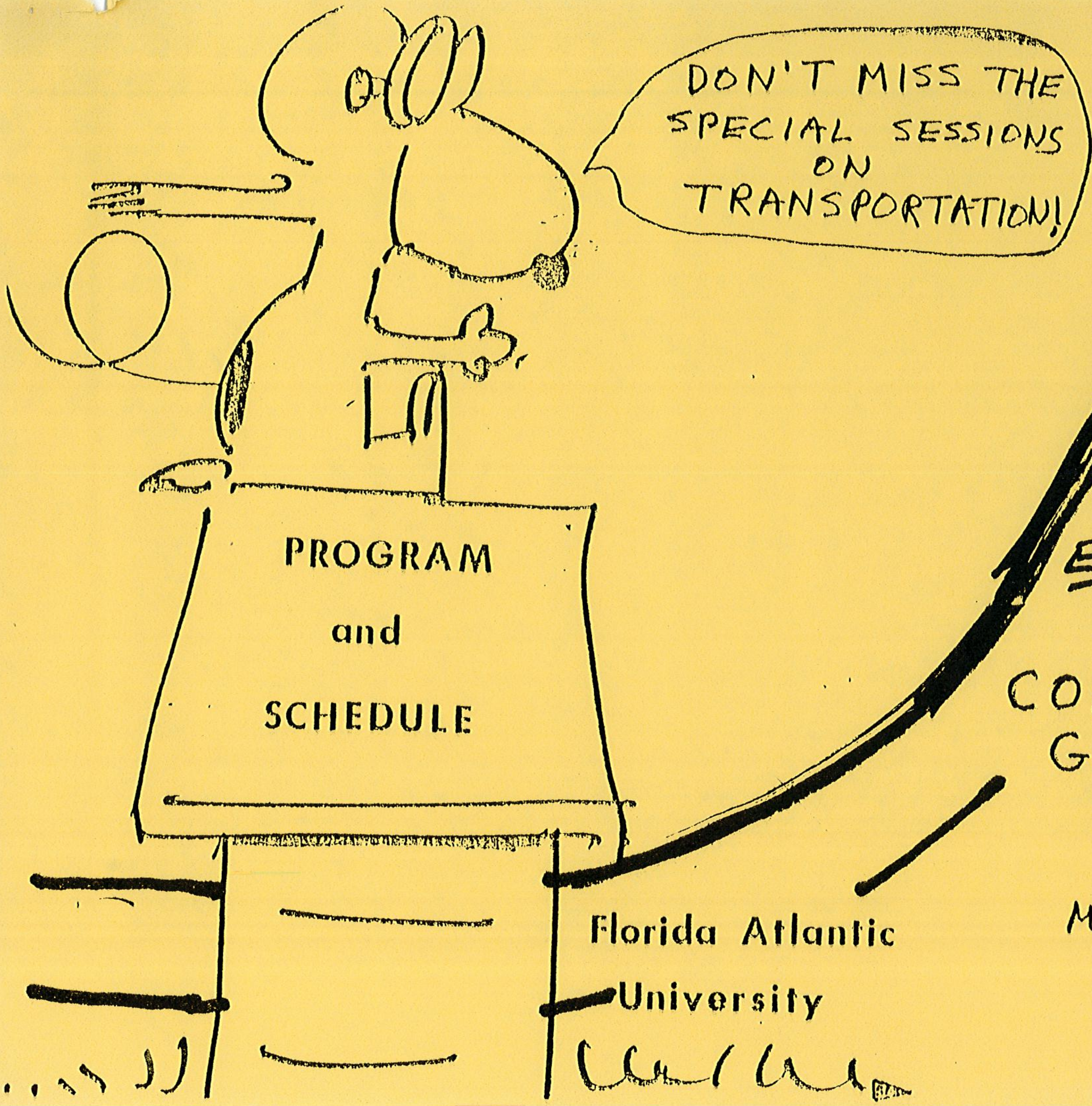

Florida Atlantic University

Eleventh Southeastern

Conference on

COMBINATORICS GRAPH THEORY & COMPUTING

March 3-7, 1980

with partial support from

DOT – Research and Special Projects Administration – Transportation Systems Center

Telephone number at Conference Desk is 2660.

GCRN and GCRS are the two halves of the Gold Coast Room of the University Center.

Room 207 is entered from the second floor lounge of the University Center.

Coffee available in Gold Coast Room South.

CONFERENCE BANQUET in Garden Ballroom of the Holiday Inn Lakeside, Wednesday, March 5, 1980. Seating at 7:00PM, service at 7:15PM. Cash bar at poolside opens at 6:00PM. There will be a van at 6:00PM at Howard Johnson's and Day's Inn.

NOTE: Conference bus will leave University Center at 5:30PM Monday and Tuesday, 5:10PM Wednesday and Thursday, and 11:15AM Friday. There will be limited transportation between University Center and Howard Johnson's Monday through Thursday, leaving the University Center at 12:10PM and leaving the motels at 1:10PM.

All Conference participants are welcome at informal gatherings to be held at Hoffman's, 4307 N.W. 5th Avenue, 6-8PM Monday, and at Freeman's, 741 Azalea Street, 6-8PM, Tuesday. We encourage car pooling, but the conference van will make pick-ups at the motels between 6:00 and 6:30PM.

MONDAY

	GCRN	GCRS	207
8:15	Registration (from 8AM)		
8:40			
9:00	Opening remarks; welcome		
9:30		L I N D N E R	
10:30		C O F F E E	
10:45	Cot 1	Hedetniemi 5	McLoughlin 9
11:05	Kotzig 2	Lau 6	Leiss 10
11:25	Abrham 3	Alspach 7	Tannenbaum 11
11:45	Friedlander 4	Simmons 8	Bramwell 12
12:00		L U N C H	
1:40		L I N D N E R	
2:40		C O F F E E	
3:00	Hsu 13	Furst 20	Pullman 27
3:20	Fuji-Hari 14	Grosky 21	Shier 28
3:40	Kramer 15	Mathon 22	Ringeisen 29
4:00	Magliveras 16	Lassner 23	Klerlein 30
4:20	Mesner 17		Klawe 31
4:40	Anderson 18	Swart 25	Babai 32
5:00	Vanstone 19	Paul 26	Zamfirescu 33
5:30	B U S		

TUESDAY

	GCRN	GCRS	207
8:15	Registration		
8:40	Straight 34	Devitt 40	Staton 50
9:00	Reid 35	Peled 41	Nowakowski 51
9:30		T H O M A S S E N	
10:30		C O F F E E	
10:45	White 36	Shapiro 42	Probert 46
11:05	Tolman 37	Niederhausen 43	Price 47
11:25	Miller 38	Hoffman 44	Golumbic 48
11:45	Gewirtz 39	J.M. Freeman 45	Savage 49
12:00		L U N C H	
1:40		T H O M A S S E N	
2:40–3:20	W A L L I S		
3:40	Neumann 52	Mills 57	Wagner 65
4:00	Goldsmith 53	Moreno 58	Call 66
4:20	Goldberg 54	Bruenn 61	Chung 67
4:40	Burstein 55	J.W. Freeman 62	Vaquero 68
5:00	Brown 56	Silverman 63	Hemminger 69
5:30	B U S		

WEDNESDAY

	GCRN	GCRS	207
8:15	Registration		
8:40	Culik 70	Whitesides 76	
9:00	Santoro 71	Funkenbusch 77	Hartnell 64
9:30		F O R D	
10:30		C O F F E E	
10:45	Vianney 72	Coxeter 78	Balas 82
11:05	Dewdney 73	Parker 79	Toan 83
11:25	Mazur 74	Rice 80	Iwata 84
11:45	Nemes 75	Payne 81	Hammer 85
12:00		L U N C H	(Conference Photo 12:05)
1:40		F O R D	
2:40		C O F F E E	
3:00	Sheffi T1	Ntafas 86	Rosenberg 59
3:20	Tingley T2	Geldmacher 87	Turgeon 60
3:40	Farley T3	Duke 88	
4:00	Gardner T4	Cozzens 89	
4:20	Glickman T5	Kundu 90	
4:40		Hell 91	
5:00	B U S A T 5:10		

THURSDAY

	GCRN	GCRS	207
8:15	Registration		
8:40	Dutton 92	Klincsek 98	
9:00	Cockayne 93	Kelly 99	
9:30			
10:30			
10:45	Burr 94	McKee 100	McIntyre 104
11:05	Grossman 95	Jamison 101	Proskurowski 105
11:25	Polimeni 96	Dowling 102	Bhat 106
11:45	Lesniak-Foster 97	Calvillo 103	Rogers 107
12:00	L U N C H		
1:40	M A G N A N T I		
2:40	C O F F E E		
3:00	Priver T6		
3:20	Thompson T7		
3:40	Benjamin T8		
4:00	Hadlock T9		
4:20	White T10		
4:40	Snider T11		
5:00	B U S A T 5:10		

FRIDAY

All Sessions in GCRN

9:00	Film on Automated Guideway Systems including Airtrans & Morgantown
9:20	Film on Downtown People Mover Simulation Program
9:40	Levow T14
10:00	COFFEE
10:20	Cooper T15
10:40	Gary Spivak - On the Miami Downtown People Mover System

Monday, March 3, Professor Charles C. Lindner of Auburn University will speak on, "A Survey of Embedding Theorems for Block Designs."

Tuesday, March 4, Professor Walter D. Wallis of the University of Newcastle (Australia) will speak on, "Hadamard Equivalences."

Tuesday, March 4, Professor Carsten Thomassen of Aarhus University (Denmark) will speak on, "Planarity and Duality in Finite and Infinite Graphs."

Wednesday, March 5, Dr. Lester R. Ford, Jr., of the General Research Corporation will speak on, "Some Implications of Computer Topology for Combinatorial Algorithms".

Thursday, March 6, Professor Thomas L. Magnanti of the Massachusetts Institute of Technology will speak on, "Combinatorial Optimization in Transportation Planning."

AUTHOR INDEX TO ABSTRACTS

(This index includes all authors. The papers are listed on the schedule by the presenters.)

A GENERALIZATION OF STIRLING NUMBERS 1

Norbert Cot*, University of Paris, France

We consider a generalization of Stirling numbers based on truncated permutations which arise in connection with some classes of random trees.

This generalization leads to generalizations of various combinatorial entities, such as harmonic numbers, etc. ...

EXISTENCE THEOREMS FOR BASES OF ADDITIVE PERMUTATIONS 2

Anton Kotzig, CRMA, Université de Montréal

A finite set $X=(x_1,\dots,x_k)$ of integers such that g.c.d.$(x_1,\dots,x_k)=1$ is called a basis for additive permutations (shortly A-basis) if there exists a permutation $(y_1,\dots,y_k)$ of X such that $(x_1+y_1,\dots,x_k+y_k)$ is a permutation of X. For $X=[a,b]$ (an interval) the A-bases were introduced and studied by Kotzig & Laufer (1978) and Turgeon (1979). Recently H. Desaulniers showed that $\{0\}$, $\{-1,0,1\}$ and $\{-2,-1,0,1,2\}$ are the only A-bases of cardinality less than 6. Denoting by $p(X)$ the number of positive elements of X we prove

(1) $2 \le p(X) \le k-3$ if $k > 5$

(2) $p(X) = k-3$ $(p(X)=2)$ for $k > 5$

$(k>6)$ and infinitely many k-element A-bases X.

GENERALIZED ADDITIVE PERMUTATIONS OF CARDINALITY SIX 3

J. Abrham (University of Toronto) and

A. Kotzig (CRMA, Université de Montréal)

Additive permutations were introduced by Kotzig and Laufer (1978) for the case when the basis of the permutation is an integer interval $\{-n, -n+1, \dots, n\}$. Recently, A. Kotzig and H. Desaulniers have shown (paper to be presented at this conference) that, if the basis of an additive permutation is of cardinality ≤ 5, it is an integer interval of the above type, and that for any integer $k>5$, with the possible exception of $k=8$, there exist infinitely many sets of cardinality k, consisting of relatively prime integers, which can serve as bases of additive permutations. In this paper we deal with the problem of finding all bases of cardinality six and the respective additive permutations. The solution consists of one two-parametric family of sets and two non-equivalent additional bases not included in this family.

Which grids are Hamiltonian? 5

Sandra M. Hedetniemi*, Stephen T. Hedetniemi*, U. of Oregon

Peter J. Slater**, Sandia Labs., (A U.S. Dept of Energy Facility)

Intuitively, a grid $G_{m,n}$ is a graph obtained from an m x n checkerboard; that is, a rectilinear, planar graph having m x n vertices, 4 of which (the corners) have degree 2, $2(m-2) + 2(n-2)$ (exterior) vertices of which have degree 3, and all remaining $(m-1) \times (n-1)$ (interior) vertices have degree 4 and are connected to their north, south, east and west neighbors. In this paper we are interested in determining for which values of m and n, and for which vertices u and v, the following grids are Hamiltonian: $G_{m,n}$; $G_{m,n}-u$; $G_{m,n}-\{u,v\}$, where u and v are adjacent; and $G_{m,n}-\{u,v\}$, where u and v are not adjacent.

*Research supported in part by the National Science Foundation under Grant MCS 7903913

**Research supported by the U.S. Department of Energy under Contract DE-AC04-76DP00789

FINDING EPS-GRAPHS 6

H. T. Lau, McGill University

In 1970, Fleischner proved a celebrated conjecture of Nash-Williams and Plummer, stating that the square of every two-connected graph is hamiltonian. A crucial step in the proof is showing the existence of a certain spanning subgraph in every connected bridgeless graph. The union S of edge-disjoint subgraphs E and P of a graph G is called an EPS-GRAPH of G if

(1) E is an eulerian (not necessarily connected) graph,

(2) each component of P is a path,

(3) S is a connected spanning subgraph of G.

If, in addition, u and v are two vertices of G such that

(4) u does not belong to P,

(5) v does not belong to P or else v has degree one in P

then S is called a (u,v)-EPS-GRAPH of G. We present an algorithmic proof of the fact that for every connected bridgeless graph G and for every choice of two vertices u, v of G there is a (u,v)-EPS-GRAPH of G.

Hamiltonian partitions of vertex-transitive graphs of order 2p 7

Brian Alspach, Simon Fraser University

We shall prove that every connected vertex-transitive graph G of order 2p, p congruent to 3 modulo 4, can be partitioned into either Hamiltonian cycles or Hamiltonian cycles and a single 1-factor depending on whether the degree of G is even or odd.

AN ANALOG DECODING METHOD 9

A. McLoughlin and R. Johnson

Certain schemes for bit-by-bit soft-decision decoding of linear binary codes in the presence of additive analog noise are considered. Let $r = (r_1,\dots,r_n)$ be the received word corresponding to a transmitted codeword $(c_1,\dots,c_n)$. Each bit c_k is estimated as 0 or 1 according as a quantity

$$\sum_j \prod_{i \in S_{jk}} f(r_i)$$

is positive or negative, where the S_{jk} are certain sets of indices related to the elements of the dual code, and f, the "decoding function," is a certain real-valued function. The optimal form for f is known [1] for the case when all parity checks are used -- j in the sum ranges over all elements of the dual code. When the dual code is large, using all parity checks is impractical. When not all the parity checks are used, the optimal decoding function f is known only in trivial cases; the methods of [1] become hard to apply. The problem of finding an optimal f is here cast as a variational problem, and an alternative derivation of results from [1] is obtained. Application of these methods to the case of a proper subset of the parity checks is discussed.

[1] C. Hartmann and L. Rudolph (1976) "An optimal symbol-by-symbol decoding rule for linear codes," _IEEE Trans. Inform. Theory_, _IT-22_, 514--517

DATA SECURITY AND BINOMIAL COEFFICIENTS 10

Ernst Leiss, Department of Computer Science, University of Houston, Houston, TX 77004

Abstract

Consider a database model where an item x is uniquely identified by a string w of k zeroes and ones such that each position in the string corresponds to a property which x may or may not have depending on whether this position in w is 0 or 1. We assume that all 2^k strings correspond bijectively to data items. A query in the database model is a string of k zeroes, ones, or asterisks; a query with exactly s asterisks will be called an s-query. The reponse to an s-query is the sum of all those data items whose bit strings are identical to the s-query except whenever the query has an asterisk the bit strings may be 0 or 1. We derive the number b(k,s) of elements which must be known in order to enable a user of this database to determine all 2^k data items using s-queries. These numbers b(k,s) are intimately related to the binomial coefficients $\binom{k}{s}$.

CONVOLUTIONAL CODES AND PARTIAL DIFFERENCE FAMILIES 11

Peter Tannenbaum, University of Arizona

Let v, r and M be positive integers. We consider a family $S_1, S_2, \dots, S_v$ of subsets of $\{0,1,\dots,M\}$ such that (1) Each S_i has cardinality r and (2) the difference triangles $D_i = \{p-q \mid p,q \in S_i;\ p > q\}$ have cardinality $\frac{r(r-1)}{2}$ and are mutually disjoint. We call such a family an (r,v) partial difference family of constraint length $N = M + 1$. Clearly $M \ge v\frac{r(r-1)}{2}$. The existence of such a family is equivalent to the existence of a self-orthogonal convolutional code having $v + 1$ message digits, v information digits and an error correcting capacity of $\left[\frac{r}{2}\right]$ errors in any span of $(v+1)(M+1)$ consecutive positions. For fixed r and v there always exists such a code for M sufficiently large. If M is minimal with respect to r and v we call the code optimal. In particular, when $M = v\frac{r(r-1)}{2}$ we call the code perfect. Several infinite families of optimal and perfect codes are constructed.

MINIMAL SEQUENCINGS OF GROUPS (9)

Richard J. Friedlander, University of Missouri-St. Louis

Given an ordering $\alpha = (a_1, a_2, \cdots, a_n)$ of the elements of a finite group G of order n, let $P(\alpha) = (b_1, b_2, \cdots, b_n)$ denote the sequence of partial products of α. Thus $b_i = a_1 a_2 \cdots a_i$ for each i, $1 \le i \le n$. Let k_α denote the number of distinct elements in $P(\alpha)$ and let $k_G = \min\{k_\alpha : \alpha$ is an ordering of the elements of G$\}$. α is said to be a minimal sequencing of G if $k_\alpha = k_G$. In this paper, minimal sequencings of all groups of order ≤ 11 are found. Using the theory of difference sets, the value of k_G is then determined for an infinite class of cyclic groups G. The notion of quasi-difference set in a group is also introduced. It is shown that if there exists a certain kind of quasi-difference set D in G, then $k_G = |D|$. This implication is examined more closely in the case where G is cyclic.

Decomposition of CTS's into Steiner triple systems

D.F. Hsu, Fordham University, Bronx, N.Y. 10458 (13)

A cyclic triple system (briefly CTS) is a pair (S,T), where S is a set of n elements and T is a non-empty collection of ordered 3-subsets of S, called cyclic triples, such that every ordered pair of distinct elements of S is contained in exactly one cyclic triples of T. A CTS on an odd number of elements does not necessarily separate into two Steiner triple systems. However, a question of much interest raised by Mendelsohn is whether one can extract and in which ways a Steiner triple system from a CTS. In this paper, a new construction of a CTS(n), $n \equiv 1, 3 \pmod 6$ is given by studying the structure of certain cyclic neofields. It is then shown that $2^{(n-1)/6}$ Steiner triple systems can be extracted from this CTS(n). This completely solves the problem of finding values n for which one can extract Steiner triple systems from a CTS(n).

DOUBLY RESOLVABLE KIRKMAN'S SYSTEMS

Ryoh Fuji-Hara* and S.A. Vanstone
University of Waterloo (14)

$K_q(v)$ denotes a collection of q subsets (blocks) from a finite set V such that every pair of distinct elements from V is contained in a unique block and the blocks can be resolved into resolution classes. Such a system is called a Kirkman System. We show that a $K_q(q^{n+1})$ is constructible from a projective plane of order q^n. The $K_q(q^{n+1})$ obtained in this manner has the same parameters as a design obtained from AG(n+1,q). Generally, it is not isomorphic. We show a necessary condition for isomorphism and a particular condition for sufficiency. Into $PG(2,q^n)$, AG(n+1,q) is embeddable. continued .....

Minimal Hamilton-Laceable Graphs† (6)

Gustavus J. Simmons, Sandia Laboratories‡, Albuquerque, NM 87185

A bipartite graph G_n with vertex sets V_1 and V_2, $|V_1| + |V_2| = n$, is defined to be Hamilton-laceable if

a) $|V_1| = |V_2|$ and for every $p \in V_1$ and $q \in V_2$

or else

v) $|V_1| = |V_2| + 1$ and for every $p, q \in V_1$, $p \ne q$

there exists a Hamilton path in G with endpoints p and q.

The minimal number of edges, E_n, for G_n to be Hamilton-laceable in case (b) is easily shown to be $\left|\frac{3n-2}{2}\right|$ by arguments similar to those used by Moon to show that the minimal number of edges for a graph G_n to Hamilton-connected is $\left|\frac{3n+2}{2}\right|$. The same question for case (a) is surprisingly difficult. For n = 4, it is easy to see that $E_n = 5 = \left|\frac{3n-2}{2}\right|$, while for all even $n = 2m > 4$ we prove:

$$3m - \left|\frac{m}{3}\right| \le E_{2n} \le 3m-1 = \left|\frac{3n-2}{2}\right| \qquad (1)$$

For n = 6, 8 and 10, $\left|\frac{m}{3}\right| = 1$ and the upper and lower bounds in (1) are the same. For n = 12 and 14 the lower bound is one less than the upper, however the minimal Hamilton-laceable graphs require 17 and 20 edges, i.e., 3m-1, in these instances. There does exist a Hamilton-laceable graph on 16 vertices which has only 22 edges! instead of 23 as might be expected. Several other instances in which $E_n < \left|\frac{3n-2}{2}\right|$ or $E_n = 3m - \left|\frac{m}{3}\right|$ are exhibited.

The question of determining E_{2n} in general remains open.

† This article sponsored by the U.S. Department of Energy under Contract DE-AC04-76DP00789.
‡ A U. S. Department of Energy Facility.

Merrick Furst, John Hopcroft and Eugene Luks, Cornell Univ.

A Subexponential Algorithm for Trivalent Graph Isomorphism 20

A technique of Babai's is improved to obtain a deterministic polynomial time algorithm for checking isomorphism between colored graphs whose color classes are of bounded size. This improvement and a novel application of Hoffmann's algorithm for cone graph isomorphism yields a subexponential, $n^{\log n}$, algorithm for testing isomorphism of arbitrary degree three graphs.

ON THE MAXIMUM NUMBER OF POINTS IN A (k,3) CAP IN THREE DIMENSIONAL GALOIS SPACE (12)

D.L. Bramwell, University of the West Indies, Jamaica

A (k,3)-cap in a three dimensional Galois space, $S_{3,q}$, is a set of k points, of which some 3, but no 4 are collinear. By using the interplay between the theory of error correcting codes and finite geometries it has recently been shown that

$$k < 2q^2 - 1, \qquad q > 4.$$

The object of this paper is to obtain the above result by the use of direct combinatorial argument.

COVERING GRAPHS WITH COMPLETE SUBGRAPHS

by

D. deCaen, University of Toronto (27)
A. Donald, University of Western Ontario
N.J. Pullman, Queen's University at Kingston

A family $\mathcal{F}$ of complete subgraphs of a graph G such that every edge of G is in at least (exactly) one member of $\mathcal{F}$ is called a clique-covering (-partition) of G. The cardinality of a clique-covering (-partition) with fewest members is called the clique-covering (-partition) number of G, denoted by cc(G) and cp(G) respectively. These parameters have been studied in the past by Erdös, Goodman and Pósa; Lovász; and Harary; and more recently by Orlin and by Ryser. We present some new techniques which enable us to calculate or estimate them for certain classes of graphs, hitherto untreated. Sample results: If G is obtained by deleting a complete subgraph on $m \ge n/2$ vertices from K_n then $cp(G) = (1/2)(n-m)(3m-n+1)$ and all (cardinality) minimal clique-partitions of G contain no members of order larger than 3. If G is a connected, k-regular graph on $n \ge k + 1 \ge 3$ vertices then $[8n(k+2)/(2(k+2)^2+(-1)^k-1)] \le cp(G) \le (kn)/2$ and these bounds are best possible.

On Chordal Graphs (28)

R. Laskar, Clemson University

D. Shier, Clemson University

This paper presents certain properties of chordal graphs - i.e., graphs in which every cycle of length greater than three has a chord. It is shown that every chordal graph on at least two vertices has at least two "complete" vertices: vertices whose neighbors form a clique. Moreover, it is shown that the diameter of any chordal graph can be realized between some pair of complete vertices. The powers of chordal graphs are also discussed.

14 continued

If $K_q(v)$ has two resolutions such that any two resolution classes from different resolutions have at most one block in common, then $K_q(v)$ is called a Doubly Resolvable Kirkman System. We show that a $K_q(q^{n+1})$, $n = 2^i - 1$, is doubly resolvable for some prime power numbers q. In the special case, $q = 3$, we show that for v sufficiently large and $v \equiv 3$ or $9 \pmod{24}$ that a doubly resolvable $DK_3(v)$ exists.

AN ASSORTMENT OF ROOM-TYPE DESIGNS 15

Earl S. Kramer, Donald L. Kreher, Spyros S. Magliveras, and Dale M. Mesner, U. of Nebraska, Lincoln NE 68588.

A t-design, or t-(v,k,λ) design, is a pair $(X,\mathcal{B})$ where $\mathcal{B}$ is a collection of k-subsets (called blocks) from a v-set X, such that each t-subset of X is in exactly λ blocks of $\mathcal{B}$. We define a Room rectangle R, denoted by $RR(m,n;\underline{t}$-$(\underline{v},k,\underline{\lambda})) \equiv RR(m,n;[t,t_1,t_2]$-$([v,v_1,v_2],k,[\lambda,\lambda_1,\lambda_2]))$, to be an m by n array such that: (i) each cell of R is empty or contains one block from an underlying t-(v,k,λ) design $\mathcal{B}$; (ii) each block of $\mathcal{B}$ appears once in R; and (iii) the blocks in any row (column) of R form a t_1-(v_1,k,λ_1) (t_2-(v_2,k,λ_2)) design. Many previous generalizations of Room squares are Room rectangles with $t_1 = t_2 = 1$. The class of all Room rectangles is large and includes infinitely many with $\max(t_1,t_2) \geq 2$, some with t_1 and t_2 at least 2, some quite interesting squares, some with no cells empty, and some higher dimensional analogues. In addition to presenting some examples of a few Room rectangles, we introduce what we call a Room graph. One of the examples of a Room graph provides an analogue of the (nonexistent) Room square of side 5.

Coherent Room Rectangles from Permutation Groups

Earl S. Kramer, Donald L. Kreher, 16
Spyros S. Magliveras, and Dale M. Mesner
University of Nebraska Lincoln

A t-design, or t-(v,k,λ) design, is a pair $(X,\mathcal{B})$ where $\mathcal{B}$ is a collection of k-subsets (called blocks) from a v-set X, such that each t-subset of X is in exactly λ blocks of $\mathcal{B}$. We define a Room rectangle R, denoted by $RR(m,n;\underline{t}$-$(v,k,\lambda)) \equiv RR(m,n;[t,t_1,t_2]$-$([v,v_1,v_2],k,[\lambda,\lambda_1,\lambda_2]))$, to be an m by n array such that: (i) each cell of R is empty or contains one block from an underlying t-(v,k,λ) design $\mathcal{B}$; (ii) each block of $\mathcal{B}$ appears once in R; and (iii) the blocks in any row (column) of R form a t_1-(v_1,k,λ_1)(t_2-(v_2,k,λ_2)) design. We say that a Room rectangle R is row (column)-coherent if all row (column) designs are isomorphic and R is coherent if it is both row and column-coherent. Room squares, or any generalizations which use 1-$(v,k,1)$ designs in both rows and columns, are automatically coherent since any two 1-$(v,k,1)$ designs are isomorphic. Using permutation-group-theoretic methods to induce t_i-resolutions of the underlying design we construct a variety of sporadic coherent Room rectangles and an infinite family of coherent Room rectangles arising from the groups $PSL_2(q)$ with $q \equiv 19$ or $31 \pmod{60}$.

TOWARDS AN ALGEBRAIC CHARACTERIZATION FOR GRAPH ISOMORPHISM

K.K. AGARWAL AND W.I. GROSKY, WAYNE STATE UNIVERSITY 21

Algorithms for graph isomorphism have received a great deal of attention due to their applicability to several practical problems such as nomenclature and planning of syntheses for organic molecules, and pattern recognition. All known general graph isomorphism algorithms are very inefficient, though some efficient algorithms are known for restricted classes of graphs such as trees and planar graphs.

We are currently studying a class of procedures with the intention of using them to solve this problem. These procedures are based on physical intuition and are interesting for this reason. We view a graph as an entity consisting of point masses and elastic edges. The graph is then suspended from each vertex to produce an invariant vector of nodal distances. Some of these procedures result in polynomial time algorithms, while some of them do not. For some of these procedures we have found counter-examples, while for others we have not. Even so, these procedures may be used to advantage in a heuristic manner.

ISOMORPHISM TESTING-POLYNOMIAL TIME?? 22

László Babai (Ohio State Univ., Columbus and Eötvös Univ., Budapest)
Rudolf Mathon (University of Toronto)

Coherent configurations are the digraph versions of association schemes. We define t-dimensional coherent configurations, where the ordered t-tuples are classified. We propose a conjecture saying, roughly, that for $t \geq 6$, regularity implies symmetry in such configurations. Regularity is defined in terms of numerical parameters while symmetry refers to automorphisms. Non-trivial t-designs would disprove the conjecture but no such designs are known for $t \geq 6$. If the conjecture is true then we obtain an $O(v^{2t+2})$ isomorphism testing algorithm, a generalization of the Weisfeiler-Lehman procedure.

GRAPH EMBEDDING ALGORITHMS:

K.K.AGARWAL, D.P.AGRAWAL and M.A.LASSNER,*
WAYNE STATE UNIVERSITY, DETROIT, MICHIGAN 48202. 23

Subgraph identification algorithms have several applications in Organic Chemistry, Pattern Recognition, Information Retrieval, Operations Research and Electrical Engineering. For the subgraph identification problem, algorithms can be no more efficient than that of the special case of recognizing a Hamiltonian path. The graph isomorphism problem is also a special case of this problem.

We present a backtracking algorithm for subgraph identification. All existing algorithms are not only fairly complex but also inefficient. In dual depth first search algorithms discussed in the literature, simultaneous searches are performed on both graphs. Our algorithm first searches the "pattern graph" in a depth first manner to build a spanning tree. Utilizing this information it searches the "goal graph" to obtain all possible embeddings.

Both recursive and nonrecursive versions of the algorithm were implemented in PL/I and FORTRAN and their performance was compared. We strongly believe that by decomposing the dual depth search algorithm into two distinct searches we have accomplished our objective of simplifying the algorithm and improving its efficiency.

On Pseudosurface Embeddings of K(m,n) and Certain Joins of Graphs 29

R.D. Ringeisen, Clemson Univ. and A.T. White, Western Michigan Univ.

A pseudosurface arises when finitely many points are identified on a surface. Questions regarding the embedding of graphs on surfaces can be rephrased in terms of pseudosurfaces. Minimizing genus in the former case becomes maximizing characteristic in the latter; the pseudocharacteristic of a graph is then the largest characteristic of any pseudosurface in which the graph can be embedded. Several pseudocharacteristic formulas are developed, including one for $K(m,n)$. The embeddings given for $K(m,n)$ are, in one-half the cases, more efficient (in terms of maximizing characteristic) than those possible in the genus situation. Applications are possible, to printed circuit theory.

Hamiltonian Groups are Color-Graph-Hamiltonian 30

J. B. Klerlein* and A. G. Starling, Western Carolina Univ.

A group Γ is said to be color-graph-hamiltonian if there is a minimal generating set Δ for Γ such that the Cayley color graph $D_\Delta(\Gamma)$ is a hamiltonian directed graph. Some recent results are used to show that hamiltonian groups are color-graph-hamiltonian.

"Generalized notions of pseudo-similarity in graphs" 31

D.G. Corneil, Dept. of Computer Science, University of Toronto.
D.G. Kirkpatrick, Dept. of Computer Science, Un. of British Columbia.
M.M. Klawe,* Dept. of Computer Science, University of Toronto.

Abstract:

Two vertices x,y are pseudo-similar if $G-x \cong G-y$ but yet $x \not\sim y$. In this paper we extend this notion to k - pseudo-similarity $x \phi^k y$ where $x \not\sim y$ and $G - \Gamma_x^k \cong G - \Gamma_y^k$ (Γ_x^k denotes the set of vertices of distance $\leq k$ from x) and full k^*- pseudo-similarity $x \phi^k y$ where $x \not\sim y$ and $x \phi^i y$ $\forall i \leq k$. It is shown that for arbitrary constants k and c, there is an infinite family of graphs with distinguished vertices $\{x_1, --, x_c\}$ such that $x_i \phi^k x_j$ $\forall i \neq j$ $1 \leq i,j \leq c$. In constrast, for any tree T there cannot exist vertices x, y such that $x \phi^k y$ for $k \geq 1$ (i.e. $T - x \cong T - y \wedge T - \Gamma_x^1 \cong T - \Gamma_y^1 \to x \sim y$). Other results on k - pseudo-similarity are also presented.

Some Room Rectangles with Density One

17

E.S. Kramer, D.L. Kreher, D.M. Mesner*, University of Nebraska-Lincoln

For definition of Room rectangles, see abstracts of talks by E. Kramer, and S. Magliveras. There are definitely many Room rectangles which have density one, that is, every cell is occupied by a block. Example and construction methods will be presented.

A NOTE ON HOWELL DESIGNS

18

B. A. Anderson Arizona State University

As in the Room Square subcase, the existence question for Howell Designs of side $3k$ and $5k$, $2,3,5 \nmid k > 1$ is complicated by the fact that there are no Room Squares of side 3 or side 5. If s is an odd positive integer, $s \geq 7$, the statement that almost all Howell Designs $H^*(s,2t)$ exist means that if $s+1 \leq 2t \leq 2s$ and $2t \neq 2s-2$, then there is a Howell Design of type $H^*(s,2t)$. Let Ψ be the set of primes p, $p \geq 7$. If $p \in \Psi$, then $p \in \Psi_1$ iff $Z_{3p} \setminus Z_3$ has a strong partial starter and $p \in \Psi_2$ iff Z_{3p} has a strong starter. Previously it has been shown that if for all p in Ψ, almost all $H^*(p,2t)$ and $H^*(5p,2t)$ exist, then if $2,3,5 \nmid k > 1$, almost all $H^*(5k,2t)$ exist. In this note it is verified that if $\Psi_1 \cup \Psi_2 = \Psi$, then the analogous statement holds for 3. Recently Ψ_1 has been shown to include most primes and in many cases, the existence of almost all $H^*(p,2t)$ and $H^*(3p,2t)$ can be shown.

The Existence of Howell Designs of Side 2n and Order 2n+2

19

P. J. Schellenberg, University of Waterloo
S. A. Vanstone, St. Jerome's College, University of Waterloo

ABSTRACT

A Howell design of side s and order $2n$, or more briefly an $HD(s,2n)$, is an $s \times s$ array in which each cell either is empty or else contains an unordered pair of elements from some $2n$-set, say X, such that

(a) each row and each column is Latin (i.e. every element of X is in precisely on cell of each row and each column) and

(b) every unordered pair of elements from X is in at most one cell of the array.

Necessary conditions on the parameters s and n are $n \leq s \leq 2n-1$

The existence of two orthogonal Latin squares of order n implies the existence of an $HD(n,2n)$. An $HD(2n-1,2n)$ is often called a Room square and it is known that these designs exist for all positive odd sides $2n-1 \neq 3,5$.

B. A. Anderson and others have shown that there exists an $HD(2n,2n+2)$ for all even sides $2n > 2$ except possibly for

$2n \in \{24,48,54\} \cup \{6p \mid p \geq 19,\ p \text{ prime}\}$

In this paper, several recursive constructions for Howell designs are described and these constructions are used to establish the existence of an $HD(2n,2n+2)$ for the above-mentioned exceptions.

WITHDRAWN

An Efficient Algorithm for Colouring the Edges of a Graph with $\Delta + 1$ Colours

24

Eshrat Arjomandi, York University

The edge colouring problem has received considerable attention from mathematicians and computer scientists. The edges of a simple graph G can be coloured with Δ or $\Delta + 1$ colours, where Δ is the maximum degree in G. Holyer has recently shown that Δ-edge-colourability is NP-complete. Many algorithms have appeared in the literature for the minimum edge colouring of bipartite graphs. The best known bound for bipartite edge colouring is $O(\min(|V|.|E|, |E|.\Delta.\log|V|, \Delta.|V|+|E|. |V|.\log|V|, |V|^2\log\Delta))$. A straight forward implementation of Vizing's theorem yields an $O(|E|.|V|)$ algorithm for the general edge colouring problem using $\Delta + 1$ colours. In this paper we present an $O(\min(|V|.|E|, \Delta.|V| + |E|.\sqrt{|V|.\log|V|}))$ general edge colouring algorithm which uses at most $\Delta + 1$ colours.

Reducibility studies of geographically good Configurations

25

E.R. Swart, University of Waterloo

Reducibility studies with respect to the four-color theorem have shown that most 'geographically good' configurations are reducible by means of existing techniques.

There are, however, some exceptions and it is possible that at least some of these exceptions can be shown to be reducible by using linear and non-negativity constraints on the color scheme frequencies.

The smallest geographically good configuration which does not reduce by means of existing techniques is 7[5665] and the application of such constraints to this configuration is discussed.

Path Length Chromatic Numbers of Z^n

26

Jerome L. Paul University of Cincinnati

Let $C^n(k) = \{(x_1,\cdots,x_n) \in Z^n : 1 \leq x_i \leq k\}$ denote the n-dimensional hypercube of lattice points having k points on a side. Using n-dimensional Tic-Tac-Toe as a model, a winning set (path) in $C^n(k)$ consists of k points in $C^n(k)$ lying on a straight line. More generally, a winning set of length k is a winning set in some translate of $C^n(k)$. For $m,n \in Z^+$, we define $\chi_m(Z^n)$ to be the minimum number of colors needed to color the points of Z^n so that all monochromatic winning sets have length at most m. Note that an upper bound for $\chi_m(Z^n)$ is immediately obtained from the fact that $\chi_1(Z^n) = 2^n$. Previous results of the author imply, in particular, that $\chi_n(Z^n) = 2$, $n \leq 3$, and $\chi_{n-1}(Z^n) = 2$, $n \geq 4$. A simple construction will be described which, together with a recent result of Ron Graham and the author, establishes certain upper bounds on $\chi_m(Z^n)$. Related results and calculations will also be discussed.

Strongly regular graphs and association schemes with large automorphism groups

32

László Babai (Ohio State Univ., Columbus and Eötvös Univ., Budapest)

The fixing number $f(X)$ of a graph X is the smallest number k such that there exist vertices $x_1,\ldots,x_k$ not fixed by any automorphism of X other than the identity. Fixing numbers are important in bounding the order of certain permutation groups. For an imprimitive strongly regular graph (kK_r and its complement) $f(X) = k(r-1) \geq v/2$. For all other strongly regular graphs X we have $f(X) < 2\sqrt{v}\log v$ where v is the number of vertices. This result generalizes to primitive association schemes and their digraph versions called coherent configurations, thereby yielding the solution of a problem of H. Wielandt on primitive permutation groups. Conjecture. $f(X) = O(\log v)$ for all primitive strongly regular graphs except the line graphs of complete and of complete bipartite graphs and their complements.

LOCAL AND GLOBAL UNILATERAL CONNECTEDNESS IN DIGRAPHS

33

CHRISTINA MARIA D. S. S. P. ZAMFIRESCU
CITY UNIVERSITY OF NEW YORK - HUNTER COLLEGE
[illegible] PARK AV., NEW YORK, NY [illegible]

The main result claims that if a weak, acyclic digraph D is locally unilaterally connected then D is also globally unilaterally connected. We then give a class of digraphs which shows that the theorem is no more true if we drop the requirement of being acyclic. An example of an infinite acyclic digraph without two-way infinite paths, which is locally unilaterally connected but not (globally) unilaterally connected is also given.

The Existence of Certain Types of Semiwalks in Tournaments

34

H. Joseph Straight, SUNY College at Fredonia

Let T be a tournament of order $n \geq 3$ and let $v_0\, v_1 \cdots v_{n-1}$ be a spanning semipath of T. We associate with this semipath a sequence $(e_1, e_2, \ldots, e_{n-1})$ of 1's and -1's such that $e_i = 1$ if $v_{i-1}v_i$ is an arc of T and $e_i = -1$ if $v_i v_{i-1}$ is an arc. This sequence is called the type of the semipath. A collision of type j is a spanning semipath having type $(1, \ldots, 1, -1, \ldots, -1)$ with exactly j 1's, while a repulsion of type j is a spanning semipath having type $(-1, \ldots, -1, 1, \ldots, 1)$ with exactly j -1's.

In 1967 Grünbaum showed that every tournament T of order n, with two exceptions, contains a hamiltonian path $v_0\, v_1 \cdots v_{n-1}$ with the property that $v_0 v_{n-1}$ is an arc of T. We present a new proof of this result, and then apply it to show that every tournament of order $n \geq 4$ contains both a collision and a repulsion of type j for each j, $1 \leq j \leq n-1$.

Tournaments with Prescribed Numbers of Kings and Serfs

K. B. Reid, Louisiana State University

35

A king (serf) in a tournament is a vertex which can reach (is reachable from) every other vertex via a 1-path or 2-path. For integers $n \geq k \geq s \geq k_s \geq 0$, $n > 0$, there exists an n-tournament with exactly k kings and s serfs and such that exactly k_s of the kings are also serfs if and only if (1) $n \geq k + s - k_s$, (2) $s \neq 2$ and $k \neq 2$, (3) $n = k = s = k_s \neq 4$ or $n > k$ and $s > k_s$, and (4) (n, k, s, k_s) is none of $(n, 4, 3, 2)$, $(5, 4, 1, 0)$, $(7, 6, 3, 2)$.

This result was announced in a preliminary report at the Tenth Southeastern Conference on Combinatorics. Preprints of the manuscript are now available.

Imbeddings of Hypergraphs

Mark Jungerman, University of California at Santa Cruz
Saul Stahl, The University of Kansas
Arthur T. White, Western Michigan University

36

A bijection between hypergraphs H and bipartite graphs G(H), where one partite set is associated with the vertices of H and the other partite set is associated with the edges of H, was described by Walsh in 1975. Each 2-cell imbedding of G(H) is readily modified to give a realization of H wherein certain of the regions of this modified imbedding depict edges of H. Imbedding problems for hypergraphs translate directly into the graphical context. Many standard results for graphs have immediate generalizations to hypergraphs, such as the euler equation, lower bounds for genus, Duke's Theorem, the Heawood Map-Coloring Theorem, and so forth. Nonorientable analogs of these results are also presented. The following specific orientable genus formula is calculated. Let H consist of n vertices and all possible $(n-1)$-subsets as edges. Then G(H) is $K_{n,n}$ less a 1-factor, and for all natural numbers n: $\gamma(H) = \gamma(G(H)) = \left\lceil \frac{(n-1)(n-4)}{4} \right\rceil$. An application to the realization of block designs is also given.

THE ENUMERATION OF COVERS OF A FINITE SET

J.S. Devitt* and D.M. Jackson
University of Waterloo

40

In this paper we enumerate the number of covers of a set by collections of subsets having the property that each element of the set occurs in exactly k subsets. We consider three types of covers. The first two are generalizations of set partitions. The third type occurs in a combinatorial decomposition of the first two types, and the enumeration of such covers may be obtained algebraically from the former.

Gaussian binomial coefficients and threshold graph enumeration

by Uri N. Peled, Dept. of Computer Science, Columbia University

41

ABSTRACT A graph is a threshold graph when numerical weights can be assigned to its vertices so that any subset of vertices with total weight not exceeding a fixed threshold is independent, and conversely. Two ways of enumerating the (unlabeled) threshold graphs by the number of vertices, edges and the size of the largest clique yield a new proof of the classical identity

$$(1+x)\,(1+qx)\,\ldots\,(1+q^{n-1}x) = \sum_{j=0}^{n} \binom{n}{j}_q q^{j(j-1)/2} x^j$$

where $\binom{n}{j}_q$ is the Gaussian binomial coefficient. Among the applications of the identity are numerous Eulerian identities in the theory of partitions and the Möbius function of the lattice of subspaces of a finite vector space.

On the Independence Dimension of a Graph

50

Glenn W. Hopkins and William Staton, University of Mississippi

For a maximum independent set I in a graph G, define $\alpha_k(I)$ to be the number of vertices of G adjacent to exactly k vertices of I. Fajtlowicz has defined the dimension of a graph G to be the largest k so that $\alpha_k(I)$ is non-zero for some maximum independent subset I of G. Fajtlowicz has proposed the problem of determining bounds on $\alpha_d(I)$, where I ranges over maximum independent subsets of G, d is the dimension of G, and G is a cubic triangle free graph. In this paper, we determine an exact answer for the case d = 2, along with some examples, and we discuss the case d = 3.

Strong Independence in Graphs

51

by John D.McFall, Saint Mary's University,Halifax,Nova Scotia,B3H 3C3
and Richard Nowakowski,Dalhousie University,Halifax,Nova Scotia,B3H 4H8

Let G be a finite graph with no loops or multiple edges. A subset of the vertex set of G is said to be independent if and only if no two vertices of S are adjacent in G. If in addition there are no independent subsets of vertices which properly contain S then we call S a maximal independent set of G. The strong independence number of G is defined to be the minimum cardinality obtained by maximal independent sets of G. Sets of vertices obtaining this minimum cardinality are called strong independent sets of G. These concepts are connected with a reliability analysis problem encountered in stochastic coherent binary systems.
In this paper we study the properties of strong independence sets and numbers. A new interpretation of the above mentioned reliability analysis problem is presented. Many open problems remain!

On the Optimal Placement of Software Monitors

Robert L. Probert, University of Ottawa

46

Program testing is widely recognized as an extremely critical component if the software development process. Yet no standard definition of testing completeness exists; in fact, "tested" software is often delivered to a user containing statements or branches which have never even been exercised during testing. One technique for exposing portions of code which have never been exercised during testing is to insert software monitors or probes into the program before testing begins. These probes gather run-time statistics about the exercising of all portions of the program during the testing process. To minimize the execution and memory overhead of such instrumentation, it is desirable to insert a minimum number of such probes into the program. In addition, it is easier to insert probes at program statements than at points of control transfers or branches. In this paper, we investigate the relationships between program structure and the ability of statement monitors to capture sufficient information to determine execution flows on program branches. In particular, we define a number of program flowgraph classes and derive a characterization of the power of instrumenting a minimum set of vertex probes. It is shown for a class of practical, structured flowgraphs, that such a set of vertex probes can always be easily found, even though for a closely related class of structured flowgraphs a vertex probe set may not exist.

Partitioning Algorithms for Program Segmentation and Processor Assignment

CAMILLE C. PRICE, The University of Texas at Dallas

47

Partitioning algorithms are applicable to the problem of segmenting computer programs for execution in a single-processor, paged-memory system, and to the problem of assigning modules of a computer program among multiple processors in a distributed system. Both problems are formulated as zero-one quadratic programming problems with linear constraints and the similarities between the two formulations are noted. The problems are modeled by search trees, and solutions are obtained to each problem through heuristic tree-search algorithms in which the search is guided by a modified objective function. Certain quadratic terms of the objective function that are difficult to obtain are ignored in the process of evaluating the promise of nodes in the search tree. The results of applying these algorithms are a computer program optimally partitioned into segments, and program modules optimally apportioned among multiple processors.

Hypergraphs

(37)

L. Kirk Tolman   Brigham Young University

A formal algebraic definition of hypergraph. Alternative geometric interpretations and some immediate consequences. Examples of theorems and/or substructures in one mathematical structure producing theorems and/or substructures in another (or may be the same) mathematical structure via hypergraph connections. A number of questions regarding the above.

"Extremal Regular Graphs"

(38)

Zevi Miller, Miami University

The problem of constructing (m,n) cages suggests the following class of problems. For a graph parameter θ, determine the minimum or maximum value of p for which there exists a k-regular graph on p points having a given value of θ. The minimization problem is solved here when θ is the achromatic number, denoted by ψ. This result follows from the following main theorem. Let $M(p,k)$ be the maximum value of $\psi(G)$ over all k-regular graphs G with p points, let (x) be the least integer of size at least x, and let $\Omega \subset \mathbb{N}$ be given by $\Omega = \{i(ik+1)+1: 1 \le i < \infty\}$. Define the function $f(p,k)$ by $f(p,k) = \max\{\lambda \in \mathbb{N} : \lambda\,(\frac{\lambda-1}{k}) \le p\}$. Then for fixed $k \ge 2$ we have $M(p,k) = f(p,k)$ if $p \notin \Omega$ and $M(p,k) = \bar{f}(p,k)-1$ if $p \in \Omega$ for all p sufficiently large with respect to k.

ON CONSTRUCTING A SPANNING TREE WITH OPTIMAL SEQUENCING

M. L. Gargano, Metropolitan Life Insurance Company
A. Gewirtz, Brooklyn College, CUNY

(39)

Consider an undirected, connected labelled graph $G = (V,E)$ with $|V| = n$ $|E| = m$. Consider also the assignment $C:E \to \{f \mid f:[0,n-1] \to R$ and f is monotone nondecreasing$\}$. Each edge is assigned a function $f_e = C(e)$ where $f_e(t)$ $(0 \le t \le n-1)$ is a monotone nondecreasing cost function giving the cost assigned by completing the construction of an edge e at time t. It is assumed that the construction of any edge in G takes exactly one unit of processing time. The edge sequence $(e_1,e_2,\ldots,e_{n-1})$ is defined to be a spanning tree with sequencing if and only if the subgraph induced by the edges $\{e_i\}$ is a subgraph which is a spanning tree of G. The problem is to construct a spanning tree with optimal sequencing, that is, a spanning tree with sequencing minimizing the maximum of the incurred costs.

A Natural Proof of Abel's Identity.

(48)

Louis Shapiro, Howard University

A proof of Abel's identity is developed by first using the Foata coding and then counting maps. This leads easily to other results counting various kinds of labelled trees.

SHEFFER POLYNOMIALS AND RECURRENCE RELATIONS

(43)

Heinrich Niederhausen, Dept. of Statistics, Stanford University

Let Q be a linear operator on the algebra of polynomials. A recurrence relation like $Qp_n(x)=p_{n-1}(x)$ with side conditions $p_n(x_n)=y_n$ can be solved by Sheffer polynomials, if Q satisfies some additional conditions (delta operator, Eulerian operator,...). We derive a general representation theorem with applications in combinatorics and statistics.

A Semigroup Related to Gaussian Polynomials

(44)

J.M. Freeman and F. Hoffman*, Florida Atlantic University

Words are defined to be sequences $\xi : \mathbb{Z}_+ \to \mathbb{Z}_+ \cup \{\infty\}$ with $\xi(n) = \infty$ for almost all n. $I(\xi)$ denotes the number of inversions in ξ, i.e., the number of pairs (m,n) with $m < n$ but $\xi(m) > \xi(n)$. The product, $\xi * \zeta$, is defined to be a "meshed juxtaposition" of ξ with the word $\zeta' = \zeta +$ maximum integer in ξ. (Terms of ζ' are meshed into the spaces '∞' in ξ.)

With these definitions words form a unique factorization (hence cancellative) semigroup, and $I(\xi * \zeta) = I(\xi) + I(\zeta)$. This is used in conjunction with MacMahon type generating functions, $\sum_{\xi \in A} x^{I(\xi)}$, to give a purely combinatorial treatment of the Gaussian polynomials.

Substitution Groups and Eulerian Differential Operators

J. M. Freeman, Florida Atlantic University

(45)

The substitutions on polynomials defined by

$$H^a p(x) = p(q^a x + \frac{q^a - 1}{q-1} K)$$

are seen to form a group (i.e. $H^{a+b} = H^a H^b$), with the translation group as a limit when $q \to 1$.

Let $\ell(x)$ be a fixed polynomial (of degree 1) which divides $(I-H)x$ and let $a \neq b$. Then the relation

$$(\ell(x)D)p(x) = H^a p(x) - H^b p(x)$$

defines an operator D on polynomials, which is, in a naturally extended sense, an Eulerian differential operator. Properties of these operators are derived, as are explicit formulae for corresponding Sheffer sequences of polynomials.

Macro Substitutions in MICRO SPITBOL - A Combinatorial Analysis

(46)

R.B.K. Dewar, M.C. Golumbic* and C.F. Goss, Courant Institute

MICRO SPITBOL is a compiler/interpreter for a variant of the SNOBOL4 programming language which runs on microcomputer systems. It is coded in a portable interpretive machine language which resides in main memory as a byte sequence. Due to restrictions on the size of main memory, it is desirable to compact this byte sequence. One technique is to define a set of macro substitutions which allow occurrences of specified byte subsequences to be replaced by single bytes. The subsequences are restored dynamically at run time by use of an associated table.

This paper analyses the problem of choosing an optimal set of macro substitutions and an order for performing the substitutions which minimizes the total length of the byte sequence and associated macro table. Polynomial time algorithms are presented for both optimal and near-optimal solutions. The techniques involve deterministic finite automaton pattern matching and finding a maximum weighted independent set of an overlap graph.

An $O(n^2)$ Algorithm for Abelian Group Isomorphism

Carla Savage, North Carolina State University

(47)

We consider the following problem: given two finite groups of order n, determine from their multiplication tables whether they are isomorphic. Tarjan has shown that this problem can be solved in time $O(n^{\log n}O(1))$. We show that if the groups are Abelian, isomorphism can be determined in time $O(n^2)$.

To do this, we define the elementary divisor sequence (EDS) of an Abelian group. It is known that two Abelian groups are isomorphic if and only if they have the same EDS. If G is a nontrivial Abelian group, the first element of its EDS is the integer p^r where $p>1$ is the smallest prime dividing the order of G and r is the largest integer for which G has an element of order p^r. Then $G \cong C(p^r) \times K$, for some Abelian group K. We show that p^r can be found in time $O(n^2)$. The fast disjoint set union algorithm is used to compute the multiplication table of K in time $O((n/p^r)^2)$. The procedure is repeated with G replaced by K as long as G has more than one element. Upon termination, the EDS for G has been computed in time $O(n^2)$.

"ABOUT CONNECTIVITY ON GRAPHS OF THE FORM $G^{=n}$"

VICTOR NEUMANN, Universidad Nacional Autónoma de México. 52

GILBERTO CALVILLO, Banco de México, S. A.

Given a graph G, and a positive integer n we defined the new graph $G^{=n}$ as the one who has the same node set as G and as arc set the paths of length n. Thus two nodes are adjacent in $G^{=n}$ if there is a path of length n joinning them. In this paper we characterize the graphs G for which $G^{=3}$ is connected. Some other results about the connectivity of $G^{=n}$ are presented.

On the Second-Order Edge Connectivity of a Graph

Donald L. Goldsmith, Western Michigan University 53

Let G be a connected graph with $p \geq 3$ vertices and $q \geq 2$ edges. $\lambda^{(2)}$, the second-order edge connectivity of G, is defined to be the smallest number of edges whose removal leaves a graph with three components. A separation of G into three components by the removal of $\lambda^{(2)}$ edges is called an "efficient" triple separation. Since it is not always obvious how many and which edges should be removed for an efficient triple separation, one is led to look for related parameters which are more readily computable. Accordingly, we consider $\sigma^{(2)} = \min(\lambda(G) + \lambda(G-S))$, where $\lambda(G)$ is the edge connectivity of G, and the minimum is taken over all separating sets S of $\lambda(G)$ edges. We have shown in an earlier paper that $\lambda^{(2)} = \sigma^{(2)}$ if $\sigma^{(2)}$ is sufficiently large. We show in this paper that if the degrees of the vertices are sufficiently large, then either $\lambda^{(2)} = \sigma^{(2)}$ or else every efficient triple separating set consists of the set of all edges incident with a single vertex v, together with a set of at most $\lambda(G) - 1$ edges in $G - v$. The lower bound given for the degrees of the vertices of G is best possible.

On trivalent graphs of class two.

Mark. K. Goldberg. 54

The new method is developed for construction of graphs with the maximal vertex degree 3 (trivalent graphs) and chromatic index 4. An infinite family of nontrivial trivalent edge-critical graphs with an even number of vertices is constructed. The description of cubic graphs of class 2 and zonnality 4 is given. The following congecture is formulated: if G is critical trivalent graph with more than one vertex of degree 2 then G is nonplanar.

UNIFORM CYCLOTOMY

L.D. Baumert
W.H. Mills* 57
Institute for Defense Analyses

Robert L. Ward
Department of Defense

Let q be a power of the prime p and let e be a divisor of $q - 1$. The e-th power cyclotomic numbers (i,j) over $GF(q)$ are said to be uniform if $(i,0) = (0,i) = (i,i) = (1,0)$ whenever $1 \leq i < e$, and $(i,j) = (2,1)$ whenever $1 \leq i < e$, $1 \leq j < e$, $i \neq j$. This property is important because it occurs many times, and when it does the cyclotomic numbers can be calculated explicitly. We show that, for $e \geq 3$, the cyclotomic numbers are uniform if and only if -1 is a power of p modulo e.

COUNTING TRACES OF POWERS OVER $GF(2^m)$ 58

Oscar Moreno, Univ. of P. Rico, Rio Piedras, P. Rico.

There is a theorem of Welch (1967) that counts the number of solutions to the equation $Tr(x^{\ell}) = 0$ in $GF(2^m)$, for certain values of ℓ. This has been found of use in Coding Theory. The present paper counts the number of solutions for further values of ℓ. This is done using the values of certain Gauss sums over $GF(2^m)$.

AUTOMORPHISM GROUPS AND EXTENSIONS OF FINITE NETS

Aiden A. Bruen*, Univ. of Western Ontario 61
Fred C. Piper, Univ. of London

We examine a situation when the automorphism group of a finite net N is transitive on the points of N. The result that we obtain may be used to construct "large" but inextendable nets (or systems of mutually orthogonal latin squares). Some generalizations are considered.

ENUMERATION OF GENERALIZED WEAK ORDERS

Carl G. Wagner, University of Tennessee 65

P. C. Fishburn (Review of Economic Studies, XLVI, 1979, 163-73) has introduced a hierarchy of generalizations of the class of asymmetric negatively transitive relations, called generalized weak orders. We exhibit recurrence relations and closed-form expressions for the number of generalized weak orders of each type in this hierarchy, and also derive generating functions and some asymptotic estimates.

Generalizations of Semiorders, Their Representation Problem, and Their Relation to Arrow's Paradox 66

Gregory S. Call and Robert Z. Norman, Dartmouth

Luce's concept of semiorder, a generalization of a strict weak order, is further generalized in a natural way to an n-semiorder for each n, bridging the gap between a complete order and an arbitrary acyclic order. In this terminology, a semiorder is a 3-semiorder and a strict weak order is a 2-semiorder. Methods of inferring an underlying (n-1)-semiorder from an arbitrary n-semiorder are discussed along with a proof that 4-semiorders cannot be represented even in two dimensions in a manner paralleling the Scott Suppes Theorem. Examples are given of n-semiorders for each n as well as a variety of 4-semiorders showing their potential degree of complexity.

Looking at the Arrow voting paradox from this point of view, strong impossibility results are obtained even when we weaken the requirement on the group ranking from a weak order to an asymmetric order satisfying a single n-semiorder axiom.

ON UNIMODALITY FOR LINEAR EXTENSIONS OF PARTIAL ORDERS

F. R. K. Chung
P. C. Fishburn 67
R. L. Graham

Bell Telephone Laboratories
Murray Hill, New Jersey 07974

R. Rivest has recently proposed the following intriguing conjecture: Let x^* denote an arbitrary fixed element in an n-element partially ordered set P, and for each k in $\{1,2,\ldots,n\}$ let N_k be the number of order-preserving maps from P onto $\{1,2,\ldots,n\}$ that map x^* into k. Then the sequence $N_1,\ldots,N_n$ is unimodal.

This note proves the conjecture for the special case in which P can be covered by two linear orders. It also generalizes this result for P that have disjoint components, one of which can be covered by two linear orders.

KURATOWSKI TYPE THEOREM FOR 2-COMPLEXES 55

Michael BURSTEIN (5557 Gasmer #283, Houston, Texas, 77035)

A simplicial 2-dimensional complex is called planar if it s associated polyhedron is embeddable into the plane. Definitions: A 2-complex is called critical if it is not planar, but it s every proper subcomplex is; a 1-simplex of a complex is called an edge if it is not contained in any 2-simplex; 1-subdivision of an edge means the substitution of this edge by a 1-dimensional path connecting it s endpoints; a 1-subdivision of a complex means a complex obtained from the original by 1-subdivisions of some of it s edges; two 2-complexes are said to be 1-homeomorphic if they have isomorphic 1-subdivisions; a 2-complex is called locally planar if each point of it s polyhedron has a planar neighbourhood.

F.Harary and R.H.Rosen charac terized locally planar complexes and posed a question: Under which combinatorial conditions a locally planar complex planar?

Theorem. Any locally planar critical complex is 1-homeomorphic to one of the following complexes:

K_5 , $K_{3,3}$,  ,  .

Clearly, any non planar complex contains a critical subcomplex.

Corollary (Rosen & Gross). A locally planar 2-complex is planar iff the 1-skeleton of it s first barycentric subdivision is planar.

Arithmetic Invariants of Simplicial Complexes 56

M. Brown and A.G. Wasserman

What invariants of a finite simplicial complex K can be computed solely from the values $v_0(K)$, $v_1(K), \ldots, v_i(K), \ldots$ where $v_i(K)$ = the number of i-simplexes of K ? The Euler characteristic $\chi(K) = \sum_i (-1)^i v_i(K)$ is a subdivision invariant and a homotopy invariant while the dimension of K is a subdivision invariant and homeomorphism invariant. C.T.C. Wall has shown that the Euler characteristic is the only linear function to the integers that is a subdivision invariant. In this paper we show that the only subdivision invariants (linear or not) of K are the Euler characteristic and the dimension.

Some Coloring Problems in a Finite Projective Plane and Blocking Sets 62

J.W. Freeman, Virginia Commonwealth University

In this paper some coloring problems in a finite projective plane and related questions on blocking sets posed by Erdös or motivated by him are discussed. Baer subplanes arise in a natural way.

Minimal families lacking property B_k 63

Ruth Silverman, Southern Connecticut State College, and Alan H. Stein, University of Connecticut

A family Γ of sets is defined to have property B_k if there is a set S, not containing any set in Γ, which contains at least k elements of every set of Γ. A dual form of property B_k was studied by P. Erdös in Nordisk Matematisk Tidskrift, Oslo (1963), and property B_k was studied by N. Levinson and R. Silverman in Proceedings, 2nd Inter. Conf. on Comb. Math, N.Y. (1970). The problem of determining the least number $m_k(p)$ of sets, each of cardinality p, which constitute a family lacking property B_k was given preliminary consideration in the latter paper. The further result is obtained, that $m_{p-1}(p) = 3$ if p is even, while $m_{p-1}(p) = 4$, if p is odd. This disproves a conjecture of Levinson and Silverman. In addition, possible approaches to calculation of $m_k(p)$ are discussed.

ON THE OPTIMAL LINEAR ARRANGEMENT PROBLEM 68

A. Vaquero & J.M. Troya, Complutense Univ., Madrid

The optimal linear arrangement of a graph is a particular case of the quadratic assignment problem with different applications. In addition to the classic application of minimizing the wiring cost for a set of interconnected modules, the problem can be applied to minimize the access time to a secondary storage device in some cases.

In this paper we present branch-and-bound algorithms to obtain an optimal solution for a determined maximum number of vertices. We describe simple procedures to compute lower and upper bounds. As initial upper bound, an approximate solution obtained from an algorithm with time complexity $O(n^3)$ is used. Then we consider a class of weighted graphs with applications to the placement of record on sequential memories in order to minimize the access time. We prove that, in some cases, an optimal solution can be obtained by a polynomial time complexity algorithm.

On n-skein Isomorphisms of Graphs 69

R. L. Hemminger, Vanderbilt University
H. A. Jung, Technische Universitat Berlin

Whitney proved that edge isomorphisms between connected graphs with at least five vertices are induced by isomorphisms and that circuit isomorphisms between 3-connected graphs are induced by isomorphisms. Halin and Jung generalized these results by showing that for $n \geq 2$, n-skein isomorphisms between (n+1)-connected graphs are induced by isomorphisms. In this paper we show that for $n \geq 2$, n-skein isomorphisms between 3-connected graphs having (n+1)-skeins are induced by isomorphisms.

Entry strong components and their application (in computer science) 90

Karel Culik, Wayne State University, Department of Computer Science

A flow diagram $Fd=\langle V,E,root,leaf,A,\Gamma\rangle$ is a rooted directed graph (or multigraph) the vertices of which are labelled by computer instructions, truth values, respectively. A vertex v of a subgraph $G=\langle W,F\rangle$ of Fd is called an entry of G if $v\epsilon W$ and there exists $w\epsilon W-V$ such that $(w,v)\epsilon E-F$. In G there always exists at least one entry. A non-trivial subgraph G of Fd is called an entry strong component (ESC) of Fd if 1) G is strongly connected, and 2) G is maximal with respect to its set of entries. Each strong component of Fd is an ESC but not vice-versa. Any two different ESC's are either disjoint or one is part of the other. An ESC with one single entry is called a loop (in computer science). Transformations of special type (which preserve function equivalence of flow digrams) are studied. They are used to prove that each Fd is function equivalent with an almost structured Fd^* (Theorem 4.3) and with a structured Fd^K (Theorem 5.5).

FORMAL SEMANTIC SPECIFICATION OF DATAFLOW LANGUAGES 112

Duc J. Vianney, Harris Corp. & Bruce D. Schriver, Univ. of S.W. Louisiana

A program written in dataflow languages (DFLs) is a directed graph in which the nodes are operators and the arcs are data paths along which data values or tokens travel. Since DFLs are built upon the mathematical notions of function, function definition, function application, function composition, etc., it is possible to express the semantics of a DFL using the functional method to specify the behavior of the various nodes. In this paper we will briefly discuss the formalization of DFLs, the concept of the virtual node firing time, and a system to specify the semantic of a DFL program. An example is included to show how such a system is being used to obtain the semantic specification of a dataflow program. This work was part of a larger effort using DFLs as a tool to model a computer organization and its operating systems.

References

1. Duc Nguyen, J.W.Anderson, B.D.Shriver, and R.E.Michelsen, "A mathematical model for a virtual machine monitor and its supportive structure," Proceedings of the Eleventh Hawaii International Conference on System Sciences, 1978.

2. Duc Nguyen, "A mathematical model for a virtual machine monitor and its supportive structure," PhD Dissertation, Computer Science Department, University of Southwestern Louisiana, Lafayette,La.,1979.

SOME PROBLEMS ON NETWORKS 64

B. L. Hartnell, Memorial University of Newfoundland

A classic problem encountered by any underground resistance movement is the question of establishing a communications network among the members of the resistance which minimizes the effects of treachery or subversion of a particular member or members, followed by the consequent betrayal of other members. The resistance movement can be represented as a graph in which the vertices portray the individual members of the movement and the edges represent lines of communication between various agents. Using this model we shall examine various aspects of this problem (For instance, we shall briefly consider the situation when communication may be one way only.).

DETERMINING TOPOLOGY INFORMATION IN DISTRIBUTED NETWORKS 71

Nicola Santoro, University of Waterloo

In networks with distributed control, topological information plays an important role. For example, in packet-switched store-and-forward networks, packets leaving a source are routed to intermediate nodes; thus, it is essential for every node in the network to have some knowledge of the topology of the network (e.g. the adjacency matrix, the distance matrix, etc.). In general, information about the network topology can be usefully employed to develop efficient network algorithms; for example, the number of steps needed to synchronize the nodes can be minimized if the radius and the center of the network are known. Unfortunately, this information cannot be derived once and for all. In fact, several unpredictable factors make the topology of the network vary in time. In this paper we are interested in determining the center and the radius of a network. Several techniques to find the (optimum) center of a (weighted) network have been presented in the literature, but all these algorithms are centralized ones and not suited for distributed networks. We present a distributed technique to determine the center and the radius of a network of unknown topology, starting from an arbitrary node. We show that the proposed method determines the center (and the radius) of an arbitrary network, starting from an arbitrary node x, in $T(x)+2$ steps, $T(x) = \lceil (2r-d)/2 \rceil + d + c(x)$, where r, d and c(x) denote the radius, the diameter and the distance of x from the diametral path, respectively. Finally, we exhibit a family of networks which require at least T(x) steps for the determination of the center; this supports our conjecture that the presented algorithm is optimal within an additive constant.

INTEGER AND FRACTIONAL MATCHINGS 82

Egon Balas, Carnegie-Mellon University

We examine the connections between maximum cardinality edge matchings in a graph and optimal solutions to the associated linear program, which we call maximum f-matchings (fractional matchings). We say that a maximum matching M separates an odd cycle with vertex set S, if M has no edge with exactly one end in S. An odd cycle is separable if it is separated by at least one maximum matching. We show that (1) a graph G has a maximum f-matching that is integer, if and only if it has no separable odd cycles; (2) the minimum number q of vertex-disjoint odd cycles for which a maximum f-matching has fractional components, equals the maximum number s of vertex-disjoint odd cycles, separated by a maximum matching; (3) the difference between the cardinality of a maximum f-matching and that of a maximum matching in G is one half times s; (4) any maximum f-matching with fractional components for a minimum number s of vertex-disjoint odd cycles defines a maximum matching obtainable from it in s steps; and (5) if a maximum f-matching has fractional components for a set Q of odd cycles that is not minimum, there exists another maximum f-matching with fractional components for a minimum-cardinality set S of odd cycles, such that $S\subset Q$, $|Q\setminus S|$ is even, and the cycles in $Q\setminus S$ are pairwise connected by alternating paths.

Collineations of Projective Planes of Order Nine 76

E. Randy Shull & S. H. Whitesides, Dartmouth College, Hanover NH 03755

At present there are four projective planes of order nine known: a Desarguesian plane, a Hughes plane, and a translation plane and its dual. The possible prime divisors of the group order of any plane of order nine are 2, 3, 5, 7, and 13, and all these occur in connection with the known planes. We show that no new planes of order nine have collineations of order 7 or 13.

Region Count for Straight Line Cutting of Flat Figures 77

W. W. Funkenbusch and R. Odendahl, Mich. Tech. Univ

An old and well known problem asks for the number of regions determined by n coplanar lines no two of which are parallel and no three of which are concurrent. Martin Gardner's Pancake Cutting Problem is equivalent: Find the maximum number of regions into which a pancake (circle) can be divided by n simultaneous cuts? "Puzzleist" Sam Loyd asked for "the maximum number of pieces that can be produced by n simultaneous cuts of a flat figure shaped like a crescent moon.

We shall derive a General Pancake Theorem for splattered batter. (Convex or concave cakes, with convex or concave holes, with convex or concave blobs of batter in the holes, with convex or concave blobs in the holes in the blobs, . . . etc.)

The edges and faces of a 4-dimensional polytope 78

H. S. M. Coxeter, University of Toronto

In 4 dimensions, the regular polytope $\{p, q, r\}$ has p-gonal faces; every edge belongs to r of them. Joining the center of each face to the midpoints of its p edges, one obtains a bipartite graph of girth 2q with alternate p-valent and r-valent vertices. In this manner the spherical honeycomb $\{3, 2, 3\}$ yields the Thomsen graph, and the simplex $\{3, 3, 3\}$ yields the Desargues-Levi graph. The most interesting case is $\{3, 4, 3\}$. Here the 288 edges can be 3-colored so as to provide the Cayley diagram for a 3-generator group of order 192:

$$T_1^2 = T_2^2 = T_3^2 = (T_1T_2T_1T_3)^2 = (T_2T_3T_2T_1)^2 = (T_3T_1T_3T_2)^2 = 1.$$

The generators appear as half-turns transforming the quaternion x into $-ix(j+k)/\surd 2$, $-jx(k+i)/\surd 2$, $-kx(i+j)/\surd 2$, respectively. The Cayley graph, regardless of color, is 3-regular, of girth 8. Its group of automorphisms is $[[3, 4, 3]]$, of order 2304:

$$A^2 = (AB^{-1}AB)^2 = (AB^{-2}AB^3)^2 = (AB)^4 = 1.$$

CENTRE-COMPANION TREES: FAST MULTIWAY TREE SEARCHING

A.K. Dewdney
The University of Western Ontario
83

Given an n-node multi-way search tree T with no outdegree restriction, it is possible to construct, in time $O(n \log n)$ its centre companion tree $C(T)$ defined recursively as follows: the initial node of $C(T)$ is a node v from the centre of T. If there is an arc of T entering v, choose the branch at v containing that arc as the subtree T_1, otherwise, let T_1 be any pendant branch at v. Let $T_2, \ldots, T_m$ be the remaining pendant branches at v. Continue this process recursively, joining v in $C(T)$ to $v_1, v_2, \ldots, v_m$ in the centres of $T_1, T_2, \ldots, T_m$ respectively. Each time the procedure reaches a subtree with one node, it backs up.

Besides pointers to other (T-subtree) centre nodes, each node of $C(T)$ contains the key information relevant to those subtrees. In the usual case of single-key retrieval where the key in T comes from a totally ordered set, $C(T)$ may be searched in time $O(\log n)$. If a node is added to or deleted from T, $C(T)$ can be reconfigured in time $O(n)$. This may not be a lower bound, however, and it remains conceivable that a $O(\log n)$ maintenance procedure will be found.

Tree Expansions of NDTM and Their Relation to Probabilistic Turing Machines

84

G.O. Mazur, RCA Astro-Electronics, P.O. Box 800, Princeton, New Jersey 08540

Abstract: The concept of enumerating paths in directed graphs by constructing trees whose paths correspond to those of the directed graph is applied here in addressing the P=NP problem of formal automata theory. Fundamentally, this paper builds upon results presented by Kozen [1] in his work on parallelism in Turing machines (Tm's). There, the construction of a deterministic P=NP automaton was based upon the concept of spawning conventional deterministic Tm's (DTM's) from a given nondeterministic Tm (NDTM). It is shown here that this concept is equivalent to the construction of a tree representing the paths in the transition function of a NDTM — a process to be referred to subsequently as tree expansion. Since each path in the tree expansion of the NDTM corresponds to a spawned DTM as described above, the number of leaves in the tree is equal to the number of DTM's required to simulate the NDTM. Hence, if by pruning the constructed tree one could reduce the number of leaves to a quantity polynomially related to the depth of a polynomially time-bounded NDTM, then P=NP would be solved. It is shown that this approach is, however, likely to fail in that an exponential amount of pruning would be required in order to satisfy the above hypothesis. In so doing, the concept of a probabilistic Tm is derived, and it is shown that such automata are capable of accepting languages accepted by polynomially time-bounded NDTM with non-zero probability in polynomial time. In conclusion, some consideration is given to the problems associated with developing algorithms for probabilistic Tm's.

[1] Kozen, D. [1976]. "On parallelism in Turing machines," IEEE Foundations of Computer Science Symposium, 17th Annual, Houston, Texas, pp. 89-97.

A Class of Self-Organizing Sequential Search Schemes

Richard Nemes and Aaron Tenenbaum, Brooklyn College
85

This paper presents a general class of algorithms for dynamically maintaining a sequential search file in approximate optimal order. It includes as particular cases the well known "move to front" and "transposition" methods. The schemes are shown to be linearly ordered with respect to certain asymptotic performance measures for a special class of search probability distributions, with the move to front rule at one end of the spectrum and the transposition rule at the other. Evidence is given that suggests that the asymptotic average search times are similarly ordered.

A SEARCH FOR NON-DESARGUESIAN PLANES OF PRIME ORDER

79

John Wesley Brown and E. T. Parker, University of Illinois

It is conjectured that all projective planes of prime order are Desarguesian; the authors made a limited search by computer for a counterexample. The known planes of orders 13 and 19 have collineations of orders 183 and 381 respectively displacing all points and all lines. We considered planes with automorphisms of orders the primes 61 and 127 respectively moving all points and lines in three cycles each; these are one-third of the preceding integers. For the smaller case we ruled out existence of new plane. The large case would have taken an exorbitant amount of time on the CDC Cyber computer, so we settled for a collineation group of order 381, generated by $x \to x + 1$ and $x \to 19x$ both modulo 127. The main part of the computation was the construction of a septuple, a quadruple and a triple of residue classes modulo 61 including each difference once among these sets. (9,7,4 for order 19.)

Winograd Convolution Algorithms over Finite Fields

80

by

Bart Rice
Department of Defense
Washington, D. C.

When computing in finite fields of small characteristic, a number of the convolution algorithms introduced by Winograd and other "Winograd-like" algorithms published by Agarwal and Cooley are either no longer valid and must be replaced by new algorithms, or else they may be improved because polynomials which are irreducible over the field of rationals Q may factor over finite fields. We derive new algorithms in a number of these cases. In addition, we discuss some of the "artistic" considerations involved in constructing Winograd convolution algorithms, including (1) the use of the notion of "transposing the tensor", which seems to have been ignored by all authors except Winograd himself when writing on this subject; (2) the simplification of that part of the discussion which involves the Chinese Remainder Theorem; and (3) the derivation of "sub-optimal" algorithms which use more multiplications than the theoretical minimum but which reduce the number of "multiplications that don't count"; i.e., multiplications which are ignored by the computational complexity theory but which in fact occur.

Generalized Quadrangles as Group Coset Geometries

Stanley E. Payne, Miami University
81

We study generalized quadrangles of order (s,t) which contain a point p for which there is a group G_p of collineations fixing all lines through p and acting regularly on the set of s^2t points not collinear with p. A coordinatization for such quadrangles of order (s^2, s) is studied and used to give an independent verification of Kantor's examples associated with the simple group $G_2(s)$ for s a prime power congruent to 2 modulo 3. In his examples the point p is shown to be the unique regular point.

ABOUT TOPOLOGICAL SOLUTIONS OF SYSTEM OF LINEAR EQUATIONS

NGUYEN KY TOAN, Département de mathématiques and ADEL F. ANTIPPA Département de physique, Université du Québec à Trois-Rivières, Trois-Rivières, Québec, Canada, G9A 5H7.
83

We derive Mason's theorem, using a topological proof which is completely independent of Cramer's rule and is based on the topological solution, recently obtained, for systems of simultaneous linear equations. This is done by codifying paths and circuits in terms of elementary paths and elementary circuits; a problem of inherent interest by itself.

MAXIMUM NUMBER OF PRIME IMPLICANTS FOR A CLASS OF RESTRICTED BOOLEAN FUNCTIONS

84

Shigeki Iwata, Sagami Inst. of Tech., JAPAN

The maximum number of prime implicants for boolean functions is considered. The maximum number has not been obtained yet. The best lower bound of the maximum number ever known is

$$\binom{n}{\lfloor n/3\rfloor \quad \lfloor (n+1)/3\rfloor \quad \lfloor (n+2)/3\rfloor} + h(n, \lfloor (n+1)/3\rfloor - 2)$$

$$+ h(n, \lfloor (n+2)/3\rfloor - 2, \text{ where } h(n,r) = 0 \text{ for } r < 0,\ h(n,0) = 1,$$

$$h(n,r) = \binom{n}{\lfloor r/2\rfloor \quad (n-r) \quad \lfloor (r+1)/2\rfloor} + h(n, \lfloor (r+1)/2\rfloor - 2)$$

for $1 \leq r \leq n$. The lower bound is $\Omega(3^n/n)$. The best upper bound is $\binom{n}{\lfloor (2n+1)/3\rfloor} 2^{\lfloor (2n+1)/3\rfloor}$, which is $O(3^n/\sqrt{n})$.

We consider a class of restricted boolean functions and show that the maximum number of prime implicants is $\binom{n}{\lfloor n/2\rfloor}$ for the class of restricted boolean functions. The maximum number is $O(2^n/\sqrt{n})$. We construct a boolean function in the class consisting of $\binom{n}{\lfloor n/2\rfloor}$ prime implicants and then show that the maximum number in the class does not exceed $\binom{n}{\lfloor n/2\rfloor}$.

GRAPHS AND QUADRATIC PSEUDO-BOOLEAN FUNCTIONS*

Peter L. Hammer, Univ. of Waterloo
85

Connections are established between the problem of maximizing an unconstrained pseudo-Boolean function and finding a maximum stable set of a graph. The special case when this connection associates a quadratic function to a graph leads to the investigation of the class of "quadratic graphs." The class of graphs for which no simplification can be derived from the knowledge of a certain class of linear majorants of the quadratic "stability function" of the graph is characterized. Many of the results have been obtained in collaboration with B. Simeone and P. Hansen.

EQUILIBRIUM ALGORITHMS FOR TRANSPORTATION NETWORKS WITH STOCHASTIC LINK COSTS (71)

Warren B. Powell and Yosef Sheffi, MIT

This paper deals with the problem of assigning origin-destination trip rates to a transportation network. We assume that each link of the network is associated with a cost that is a function of the link's flow. We also assume that users do not perceive the link cost accurately but rather model the link costs as random variables distributed across the population of trip makers. We show in this paper that the problem can be cast as a minimization problem. We also suggest a solution algorithm and prove its convergence. In the last part of this paper we strengthen the conclusion in some of our earlier work with regard to the merits of the additional effort involved in performing stochastic equilibration versus a deterministic one -- this effort may not be justified for high levels of congestion. This and other points in the paper are demonstrated with a small network example.

The European Aircrew Assignment Problem (72)

G.A. Tingley, SWISSAIR

The scheduling of European airline crew members consists of individual assignment of the crew member to tasks, called rotations, which are chains of flight segments which can be legally flown by some, if not all, of the crew members. The rotations last five days, typically, in the European sector. These rotations are in effect overlapping, staggered shifts. This is different from the North American situation where monthly "lines of work" are prepared by the airlines and then put out for bid by the crew members.

This is a quadratic assignment problem. It is similar to the minimum longest finishing time machine scheduling problem, but with the complications of non-independent tasks, non-interchangeable processors, and preassignments. The incompatibilites among the tasks and the individual restrictions on the processors provide difficulties in achieving a complete feasible solution.

No exact solution methods have been implemented in the airlines yet, however some approximate methods are in use. They usually decompose the monthly problem into daily subproblems. Some of these are described, together with a recently proposed method based upon a rolling schedule approach, using the out of kilter algorithm and Philip Hall's theorem, to overlapping daily subproblems.

On the Complexity of Some Minimum Path Cover Problems (86)

SIMEON NTAFOS, The University of Texas at Dallas

Dilworth's theorem relates the size of a minimum path cover for the vertices of an acyclic digraph $G = (V,E)$ to an independence number of the digraph. In this paper, we attempt to generate Dilworth-type theorems for situations where additional requirements are placed on the path cover and/or restrictions are placed on the paths that can be included in the path cover. Furthermore, the algorithmic complexity of these problems is considered. In particular, we look at the problems of finding minimum path covers for a) a set of required pairs/paths of G, b) the vertices of G when a set of impossible pairs/paths is specified for G, c) a set of vertex subsets $V_i \subseteq V$ and d) the vertices of G when an upper limit is placed on the length of any path in the cover.

A O(n) ALGORITHM FOR FINDING A SUBGRAPH HOMOMORPHIC TO K_4 (87)

P.C. Liu, Environplan, Inc.
R.C. Geldmacher, Stevens Institute of Technology

Abstract In [1] a theorem is given which characterizes a graph as non-reducible if and only if it contains a subgraph homomorphic to K_4. Reducibility is defined in terms of transformations which generate a coalescing process of the vertices and edges of a graph. These transformations are: replacement of a dangling edge uv with u, replacement of two series edges uv and vw with uw, replacement of a loop vv with v, and replacement of two parallel edges uv and u'v' with uv. If G' is the resultant graph after applying the transformations to a graph G until no longer possible, then G' is reducible if it consists of a single vertex. Otherwise G is nonreducible. If G' = G then G is irreducible. If a graph contains subgraphs homomorphic to K_4 the algorithm will identify a set of corner vertices of one such subgraph. The algorithm employs depth first search with back tracking and has time and space complexities proportional to the number of vertices of a graph.

[1] P.C. Liu and R.C. Geldmacher, "Graph Reducibility", Proceedings of the Seventh Southeastern Conference on Combinatorics, Graph Theory, and Computing.

A Problem on Complements and Disjoint Edges in a Hypergraph (88)

Richard A. Duke
Georgia Institute of Technology
(currently visiting at Emory University)

Paul Erdős
Mathematical Institute of the Hungarian Academy of Sciences

We consider various questions inspired by the following conjecture: "Let G be a k-uniform hypergraph on n vertices with ℓ k-sets as edges. If the complement of each set of k-1 vertices contains at least k edges, then G has two disjoint edges." It is easy to see that the conjecture is true for $k = 2, 3$ and when $n = 2k$. It is also true for sufficiently large n. Examples which we have found, and others constructed by P. Frankl, show that the conjecture is not correct in general, but many questions remain. If the conjecture is not true for a given k, what is the smallest value of $n = n_0(k)$ for which a counterexample exists? What is the smallest value of $\ell = \ell(k)$ for which there is a counterexample? What is the smallest value of $n_1(k)$ such that for $n > n_1(k)$ the conjecture is true again? Finally, what is the smallest value of $f(k)$ such that if the complement of each $(k-1)$-set contains $f(k)$ edges, then G has two disjoint edges? Our smallest counterexamples have $k \geq 6$ with $n < ck^2$ and $\ell < c'k^4$ or with $n < 3k$ and $\ell > 2^{k/2}$.

CYCLE STRUCTURE OF AFFINE TRANSFORMATIONS OF VECTOR SPACES OVER GF(p) (59)

Ivo G. ROSENBERG, CRMA Université de Montréal

Let p be prime, m positive integer and V_m the m-dimensional vector space over GF(p) (i.e. the set of column m-vectors over $p = \{0,\dots,p-1\}$ with componentwise mod p and scalar mod p multiplication). A selfmap $\varphi : x \to Mx + N$ $(x \in V^m)$ where M is an $m \times m$ matrix over p and $N \in p^m$ is called affine. The problem is the abstract characterization of an affine map in terms of the associated digraph ; in particular its cycle structure if M is non-singular. The question arose in the context of finite universal algebras. We show that cyclic affine permutations exist if an only if $m = 1$ or $p = m = 2$. Similarly we discuss the case of affine permutations with all cycles of length $.p^{m-1}$

FURTHER RESULTS IN THE THEORY OF PERFECT SYSTEMS OF DIFFERENCE SETS (60)

Jean M. TURGEON, Université de Montréal, CANADA

The theory of perfect systems of difference sets has progressed in several directions in the past year: existence of small components, a partial proof of Erdős' conjecture, construction of additive sequences of permutations of various types. Recent results of Abrham, Desaulniers, Kotzig, Laufer, Rogers and myself shall be surveyed.

Title: The Boxicity of a Graph (89)

Author: Margaret B. Cozzens Rutgers University

Define the boxicity of a graph G, b(G), to be the smallest integer k such that G is representable as the intersection graph of boxes in $\mathbb{R}^{(k)}$. This concept has applications in a variety of applied areas: airplane maintenance scheduling, determination of ecological niche space, amino acid formation in protein molecules, etc. In this paper we prove that determining the boxicity of a graph is an NP-complete problem. However, for rigid circuit graphs the boxicity is completely determined and a polynomial time algorithm is given to determine if $b(G)\leq k$ for each k. It is also shown that the boxicity of a rigid circuit graph is less than or equal to $\left\lceil\frac{n-1}{4}\right\rceil$ where $n=|V(G)|$ and less than or equal to $\left\lceil\frac{\alpha}{2}\right\rceil$ where α is the independence number of G. If G is a split graph (both it and its complement are rigid circuit) with degree sequence of $\tilde{G}=d_1\geq d_2\geq \dots \geq d_n$ and $m=\max\{i|d_i>i-1\}$, then $b(G)\leq\left\lceil\frac{m}{2}\right\rceil$.

$\lceil x\rceil$ denotes the least integer greater than or equal to x.

Levelling Terrain Trees: A Transshipment Problem

Arthur M. Farley, University of Oregon T3

The problem investigated is that of planning a set of truck loads to redistribute earth from high points to low points of a proposed road network. Such problem situations are modeled by terrain graphs - a class of (vertex and edge) labelled, undirected graphs. An algorithm is presented which determines minimum-load, minimum-cost levelling plans for an arbitrary terrain tree. The algorithm can be implemented to have time complexity of the order of the sum of the number of high and number of low points (i.e., the number of vertices) in the tree. The problem solved by the algorithm is an example of the (uncapacitated) transshipment problem restricted to trees. Linear Programming methods which solve the transshipment problem for general graphs have time complexity of the order of the product of the number of high points and (sources) and number of low points (sinks).

Applications of an algorithm for networks T4

M.L. Gardner, North Carolina State Univ. & Univ. of Michigan

We will briefly describe an efficient algorithm for finding all the min-cuts of a network and then apply it to problems in warehouse allocation, database management and network reliability.

NETWORK ANALYSIS OF A NATIONAL POLICY FOR ROUTING RAIL HAZARDOUS MATERIAL SHIPMENTS T5

Theodore S. Glickman, Ph.D.
U.S. DOT/Transportation Systems Center

Alain L. Kornhauser, Ph.D.
Princeton University

The restricted routing of hazardous materials shipments on the nation's railroads has been proposed as a possible means of reducing the associated risk. In this analysis, a simulation of the historical transportation patterns is obtained using a network model and a sample of shipping records. Altered patterns based on different degrees of population avoidance are then generated. Railroad-based estimates of the changes in carmiles, average haul, population exposure and expected casualties are computed for each case. The tradeoff is made apparent between reductions achieved in population exposure vs. higher accident rates resulting from diversion to poorer track.

AN O E ALGORITHM FOR COMPUTING TRANSITIVE REDUCTION OF A PLANAR DIGRAPH 90

Sukhamay Kundu, Bell Laboratories

There have been numerous attempts in the past twenty years to obtain efficient algorithms for computing the transitive closure of a digraph. The first transitive closure algorithm was given by B. Roy in 1959 which was subsequently rediscovered by Warshall in 1962. The current renewal of interest in the transitive closure/reduction problem has its origin in two recent discoveries by Munro and Meyer in 1971 and by Aho, et al. in 1972. They showed respectively that the transitive closure problem is computationally equivalent to boolean matrix multiplication and is also equivalent to the problem of computing transitive reduction, provided the digraph is acyclic.

In this paper, we present a linear $O(E)$ algorithm to compute the transitive reduction of a planar acyclic digraph, where E equals the number of arcs. The best previously known algorithm for computing transitive reduction of a general acyclic digraph has the time bound $O(V^{2.8})$, where V equals the number of nodes, and uses Strassen's matrix multiplication method. For sparse digraphs, another algorithm by the author has the best time complexity $O(V.E_*)$, where $E_* \le E$ denotes the number of arcs in the transitive reduction.

The planar digraphs forms the second such class of digraphs for which linear transitive reduction algorithms are known to exist, the other class being the digraphs whose transitive reductions are spanning directed trees. The algorithm given here demonstrates an interesting interplay between the topological concept of planarity and the algebraic concept of transitive reduction. While the algorithm for planar digraphs makes explicit use of a fixed (but otherwise arbitrary) planar representation, the algorithm for the other class of digraphs does not assume any apriori knowledge of their special property.

VERY NON-(TRANSITIVELY-ORIENTABLE) GRAPHS AND PARALLEL ALGORITHMS WITH CONSTANT TIME FOR COMPARISONS. 91

Roland Häggkvist and Pavol Hell*, Rutgers University.

The following problem arises in testing consumer preferences: A linearly ordered set of n elements is given, and one is to discover the order (respectively discover its largest element) by performing binary comparisons arranged in two rounds: In the first round a set of comparisons is performed, then the answers are evaluated, and another set of comparisons is formulated for the second round. We prove using probabilistic methods, that there exist sparse graphs for which every acyclic orientation has a dense transitive closure. It follows that it is possible to arrange the comparisons so that a total of only $O(n \log n)$ comparisons will suffice to sort the set. In contrast, it takes n comparisons to discover the largest element. We also obtain lower bounds and generalize our results to k rounds. The problem can be viewed as one of calculating the minimum number of parallel processors needed to sort (respectively find the largest element of) an n-element linearly ordered set in k time intervals.

C-GRAPHS ARE RECOGNIZABLE AND EDGE-RECONSTRUCTABLE 92

R. D. Dutton and R. C. Brigham UCF

We define a C-graph as a graph which possesses a set of $K \ge 2$ nodes which induce a clique while all edges not in the clique have exactly one end point in that set. It is then shown that every simple graph, no loops or multiple edges, is either a C-graph or it possesses as induced subgraphs at least one of C_4, $\bar{C}_4$, or C_5 where C_p is the cycle on p nodes and $\bar{C}_p$ is the complement of C_p. Recognition of C-graphs from either the set of node-deleted or edge-deleted subgraphs is possible. Partial results concerning node-reconstruction are presented as well as the general result that all C-graphs are edge-reconstructable.

ON ROTATION NUMBERS FOR COMPLETE BIPARTITE GRAPHS 93

E.J. Cockayne*, Univ. of Victoria, Victoria, B.C., Canada
P.J. Lorimer, Univ. of Auckland, New Zealand

Let G be a simple undirected graph which has p vertices and is rooted at x. Informally, the rotation number $h(G,x)$ of this rooted graph is the minimum number of edges in a p vertex graph H such that for each vertex v of H, there exists a copy of G in H with the root x at v. In this paper we calculate some rotation numbers for complete bipartite graphs.

FINDING LARGEST CONVEX SUBSETS 98

V. Chvátal and G. Klincsek*, McGill University

A set of k points in the ordinary plane is sometimes called *convex* if it consists of the vertices of some convex k-gon. J. Michael Steele asked for an efficient algorithm to find the largest convex subset of a prescribed set of n points. The purpose of this note is to present a dynamic programming algorithm performing this task with time and storage requirements $O(n^3)$ and $O(n^2)$, respectively.

Random polytopes and random linear programs 99

Douglas G. Kelly, University of North Carolina

We consider a class of probability distributions on linear programs in n variables with m constraints; this class includes most of the random-generation schemes used in testing and comparison of versions of LP algorithms.

We derive an integral expression for the expected number of vertices of the feasible region of a random problem. This leads to asymptotic upper and lower bounds that show that the expected number of vertices is, for large m and n, linear in m and approximately of order (n to the power n/2) in n.

These results have connections with recent experimental results on the expected number of simplex pivots needed to solve a random linear program.

Trees in Directed Graphs and Hypergraphs 94
Stefan A. Burr, City College, CUNY, N.Y., N.Y.

The following theorem is proved: Let T be a tree on n points with its edges oriented in an arbitrary manner. Then any directed graph with chromatic number at least n^2 has T as a subgraph. (The n^2 can be improved.) This result can be extended to hypergraphs; an application of this to generalized Ramsey theory for graphs is given.

Ramsey Numbers of Graphs with Long Tails 95
Stefan A. Burr (C.U.N.Y.) and Jerrold W. Grossman* (Oakland University)

A simple canonical 2-coloring of the edges of K_r shows that the ramsey number of a connected graph G must be at least $r = (p(G) - 1)(\chi(G) - 1) + s(G)$, where $p(G)$ is the number of points of G, $\chi(G)$ is the chromatic number of G, and $s(G)$ is the minimum, taken over all $\chi(G)$-colorings of the points of G, of the number of points in the smallest color class. It is shown that in fact the ramsey number of G is r if $\chi(G) \geq 3$ and G has a sufficiently long tail emanating from one of its points.

LOGICAL AND MATROIDAL DUALITY IN COMBINATORIAL LINEAR PROGRAMMING
T. A. McKee, Wright State University 100

During the last dozen years, a number of papers have appeared dealing with a combinatorial version of the Duality Theorem of Linear Programming and its relation to Minty's Colored Arc Lemma. While the usual statements of these results are both colloquial and colorful, this paper provides syntactical restatements from which their underlying structure and similarity becomes more evident. They are shown to be "logical principles" involving the interplay between logical and matroidal duality.

Antimatroids
Robert Jamison-Waldner, Clemson University 101

This report deals with a finite Krein-Milman property for closure systems which occurred in some unpublished work on abstract convexity a number of years ago. If has persistantly reappeared in various contexts: integer programming, ordered spaces, semilattices, chordal graphs. It can also be formulated as an "antiexchange" law (hence the title) and has a number of other useful reformulations. The principal goal here is to collect the known equivalences to this property, to discuss some of its applications, and to describe the main situations in which this property occurs.

On the number of independent sets of
a finite matroid 102
T. A. Dowling, Ohio State University

The numbers I_k of independent sets of size k in a finite matroid have been conjectured to form a unimodal sequence. We describe a stronger conjecture and establish some partial results. A consequence is that the sequence satisfies the log concavity property

$$I_k^2 \geq I_{k-1} I_{k+1}$$

for $k < 7$.

A CHARACTERIZATION THEOREM FOR THE LOCAL BEHAVIOR OF THE MINIMUM DEGREE ALGORITHM 104

David R. McIntyre, Cleveland State University

In this paper we prove a theorem which characterizes the local behavior of the minimum degree ordering algorithm (MDA) for general symmetric positive definite linear systems. Several equivalent graph theoretic theorems are also proved. These theorems establish the validity of mass elimination techniques used in most modern implementations of the MDA (for example, sparse matrix packages of Waterloo and Yale). Also, recently they have been used by the author to prove that an implementation of the MDA [1] automatically provides a block column storage scheme for the Cholesky factors which is optimal in the sense of having the fewest number of diagonal and off-diagonal dense blocks.

REFERENCE

[1] Alan George and David R. McIntyre, On the Application of the Minimum Degree Algorithm to Finite Element Systems, SIAM J. NUMER. ANAL. Vol. 15, No. 1, 1978.

K-TREES: REPRESENTATIONS AND DISTANCES 105
Andrzej Proskurowski, University of Oregon

A class of graphs that can be constructed from a k-complete "base" by iterative addition of a new vertex adjacent to some k completely connected "old" vertices is called k-trees. The iterative construction can be represented by a (k+1)-dimensional tree with nodes corresponding to (k+1)-cliques of the k-tree. Another, more specific representation is the recursive representation involving associating consecutive integers to the vertices of the k-tree as they are appended to the constructed k-tree.

Using the notion of a "cable" consisting of k vertex-disjoint path between two vertices of a k-tree, we define the k-cable distance is a k-tree. We discuss the values of the shortest-path and the k-cable distances between vertices of a k-tree in terms of different representations of the tree.

ELEMENTARY MODIFICATION OPERATION IN A TREE AND BICYCLE REALIZABILITY OF A DEGREE LIST* 106
Kabekode V.S. Bhat, Comp. and Info. Sc., Ohio State Univ.
Parviz Rashidi, Comp. Sc. and Engin., Pahlavi Univ., Iran

An elementary modification operation in a tree that preserves its degree list is defined. A characterization for bicycle graphs is presented. Using the elementary modification operation and properties of bicycle graphs a simple set of necessary and sufficient conditions for a list of integers to be degrees of vertices of a bicycle graph are derived.

Graphs Which Arrow the Pair (T_m, K_n). 96
A. D. Polimeni, H. J. Straight, J. E. Yellen (State University College, Fredonia, NY 14063)

Abstract. For an arbitrary tree T of order $m \geq 2$ and an arbitrary positive integer n, Chvátal proved that the ramsey number $r(T,K_n) = 1 + (m-1)(n-1)$. For graphs G, G_1 and G_2, we say that G arrows G_1 and G_2, written $G \to (G_1, G_2)$, if for every factorization $G = R \oplus B$, either G_1 is a subgraph of R or G_2 is a subgraph of B. It is shown that:

(1) for each $\ell \geq 2$, $K_{1+(m-1)(n-1)} - E(K_\ell) \to (T, K_n)$ for $m \geq 2\ell - 1$ and $n \geq 2$.

(2) $K_{1+(m-1)(n-1)} - E(H) \to (T, K_n)$, where H is any tree of order $m - 1$, $m \geq 3$ and $n \geq 2$.

It is further shown that result (1) is sharp with respect to the inequality $m \geq 2\ell - 1$, and result (2) is sharp with respect to the order of H.

BALANCED RAMSEY NUMBERS 97

G. Chartrand and L. Lesniak-Foster*, Western Michigan University
C.E. Wall, Old Dominion University

For graphs G_1 and G_2, the balanced ramsey number $r_b(G_1, G_2)$ is the least positive integer n such that if $p \geq n$ and $K_p = F_1 \oplus F_2$ is any factorization of K_p for which $|q(F_1) - q(F_2)| \leq 1$, then either $G_1 \subset F_1$ or $G_2 \subset F_2$. Balanced ramsey numbers are determined for several pairs of graphs G_1 and G_2.

CHARACTERIZATION OF THE MATROID POLYTOPE
BY MEANS OF THE INTERSECTION PROPERTY 103

GILBERTO CALVILLO. Banco de México, S. A.

The convex hull of the independent sets of any matroid has been characterized by Jack Edmonds as the solution of a system of linear inequalities and also, in a more geometric way, in polymatroid theory. In this paper a rather different characterization is obtained using the concept of intersection property, introduced in a previous paper. The characterization is as follows: A polytope P corresponds to a matroid if and only if P is contained in the unit hypercube and

a) if $0 \leq x^\circ \leq x'$ and $x' \in P$ then $x^\circ \in P$

b) For any integer k and any 0-1 vector q, the polytope obtained by intersecting P with the hyperplane $qx=k$ has no fractional vertices.

Graceful Graphs: Some Further Results and Problems 107
K.M. Koh & D.G. Rogers, Nomyang Univ., Singapore

We review recent work on graceful graphs and pose some further problems arising from this.

Research Topics in Automated Guideway Transit (T6)

Arthur S. Priver, U.S. Dept. of Transportation

Automated Guideway Transit (AGT) systems can be deployed in a wide spectrum of applications ranging from simple loops and shuttles to complex grid networks. Among the considerations for defining cost-effective deployments are such concerns as network and route design. When are one-way links used in preference to two-way links? How many routes are feasible with given vehicle fleet size constraints? What performance measures relate to the efficiency of network layout? What are the best computer representations of the networks?

For alternative failure management strategies, the number of routing alternatives (disjoint paths between any pair of nodes) is significant. Criteria have to be developed for the number of crossovers and bypasses to employ. Specific applications are discussed, including the Downtown People Movers, Airtrans, and Morgantown.

AGT GUIDEWAY LAYOUT AND EVALUATION (T7)

Jim Thompson, General Motors Transportation Systems Center

During the process of developing an AGT system deployment, one of the major design problems is to establish guideway routes and station locations. While a body of sohpisticated optimization theory and associated computational techniques exists, these techniques presume a set of well-defined criteria of optimality. In practice, selection of route and station locations is an iterative and frequently political process in which the criteria applied can be subjective, poorly defined, and often contradictory. In such a situation, the engineer needs the capability to model his basic data (e.g., geographic, demographic, modal split and performance information) and then quickly test alternative solutions. As much as possible, he should not be constrained by built in, a priori assumptions about how results should be aggregated, manipulated, or displayed. The use of graphic should be emphasized for both data input and output since non-engineers are usually involved in the decision-making process. Finally, the system should be capable of interfacing with a variety of external computer programs or data sets so that existing, locally calibrated models and data files can be utilized directly.

ALTERNATIVE ROUTING ALGORITHMS FOR AN AUTOMATED GUIDEWAY TRANSIT SYSTEM (T8)

David E. Benjamin | Vought Corporation |

The AIRTRANS people mover system at the Dallas/Fort Worth Regional Airport is the largest automated guideway transit (AGT) system in the world today. The system was built by the Vought Corporation in the early 70's and went into revenue operation when the Airport opened in January 1974. In the AIRTRANS system, 68 fully automated vehicles operate over the 13 miles of single lane guideway. The complex system includes 33 diverge and 38 merge type switches, 48 stations and a total of 702 control blocks. While early system conceptual designs examined the possibility of implementing vehicle routings which would be responsive to passenger demand, the system as built operates strictly with fixed routes. None the less, the AIRTRANS system seems ideally suited for some sort of demand responsive service policy. As part of the Urban Mass Transportation Administration's AIRTRANS Urban Technology Program, alternative demand responsive routing algorithms were examined. This paper will discuss the development that went into the algorithms which were studied, the results of the computer simulation analysis of the various algorithms, and a comparison of these results with the currently implemented fixed route schemes.

INTERACTIVE TRANSPORTATION SUPPLY MODELLING (T10)

WALLACE W. WHITE BOEING COMPUTER SERVICES CO.

The purpose of this paper is to present a description of graph theoretical and combinatoric techniques used in an interactive surface transportation model developed and currently in use at the Boeing Company. The final segment of the paper presents a discussion of some unsolved (in the practical applied sense) problems for this area of application.

Minimum Cost Route Selection (T9)

F. Hadlock, Florida Atlantic University

A branch and bound algorithm is developed to select from a list of potential routes the set which minimizes total system cost (combines both operating and travel time costs). The algorithm could be used for selecting routes for fixed schedule service in a small automated guideway transit system.

BOEING AGRT ANALYTIC NETWORK MODEL (T11)

by Gregory Snider* and Alice Chen, The Boeing Company

During development of the Advanced Group Rapid Transit (AGRT) system, the analytic network model has proven itself to be a reliable and useful analysis tool. The steady-state model is interactive, quick, and relatively inexpensive. The latest generation of the model consists of a set of three sequential parts: a file generator, a computations section and a report generator. The file generator is used periodically to prepare network-specific calculations, while the remaining portions are run-specific and are utilized for each case. Network-specific calculations include a minimum-path algorithm and a demand expansion to assure station correspondence. The computations section consists of a vehicle scheduling mode option (scheduled or mixed demand-scheduled operation) and a pooled-inventory balancing scheme. Finally, the report generator allows specification of the format and content of outputs. Examples of model operation from the analysis of a 50-mile network are provided. Operational service policies which are to be added when the model is revised are also covered.

The Impact of DESM Simulation Strategy on System Performance

Roy B. Levow, Florida Atlantic University (T14)

In this paper we first briefly review the architecture of the Discrete Event Simulation Model (DESM) model processor subsystem. We then examine the influence of the model processor architecture on the capability of the DESM system to handle specific design features and scheduling protocols for automated guideway transit systems. Finally, we discuss a simple approach to extending the capabilities of DESM within the scope of the present system architecture and comment on the limitations inherent in the suggested approach.

Queueing Theory in Transportation Engineering: A Tutorial

Robert B. Cooper, Florida Atlantic University (T15)

It seems reasonable that the mathematical theory of queues should be applicable to the construction and analysis of models of transportation systems. The purpose of this talk is to give an overview of queueing theory, with emphasis on its strengths and weaknesses as a modeling tool for transportation engineering. The ideas will be illustrated by consideration of a simple model of an AGT network in which the capacity of a station is determined by assigning the probability that a vehicle will find the station full. The talk will be informal, with the intention that its direction will be guided by questions and comments from the audience.